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DESIGN RESTRICTIONS AND LICENSING FOR
PETITE AMATEUR NAVY
SATELLITE (PANSAT)

by

Robert R. Rowsey

September 1990

Thesis Advisor R. Panholzer

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The small inexpensive Petite Amateur Navy SATellite (PANSAT) is the Naval Postgraduate School (NPS) Space Systems Academic Group's first experience with real-time space operations. Propelled by the success of PANSAT, NPS will follow this project with more complex space systems such as ORION. This thesis discusses the general and specific design considerations and constraints encountered during the design of PANSAT, along with providing descriptions of the satellite's various subsystems. The study also addresses the problems and procedures associated with obtaining a license frequency assignment for PANSAT. Three viable licensing options, an amateur, a military and an experimental option are presented. The thesis also includes a detailed decription of the national and international frequency regulatory agencies, for better understanding of the licensing procedures.

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Design Restrictions and Licensing for Petite Amateur Navy Satellite (PANSAT)

by

Robert R. Rowsey
Captain, United States Marine Corps
B.S., United States Naval Academy, 1984

Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

The small inexpensive Petite Amateur Navy SATellite (PANSAT) is the Naval Postgraduate School (NPS) Space Systems Academic Group's first experience with real-time space operations. Propelled by the success of PANSAT, NPS will follow this project with more complex space systems such as ORION. This thesis discusses the general and specific design considerations and constraints encountered during the design of PANSAT, along with providing descriptions of the satellite's various subsystems. The study also addresses the problems and procedures associated with obtaining a license/frequency assignment for PANSAT. Three viable licensing options, an amateur, a military and an experimental option are presented. The thesis also includes a detailed decription of the national and international frequency regulatory agencies, for better understanding of the licensing procedures.

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I. INTRODUCTION

The purpose of this study is to address the various design considerations associated with the development of the Naval Postgraduate School's (NPS) Petite Amateur Navy SATellite (PANSAT). In addition, the thesis presents the options available for obtaining a frequency channel for the satellite.

PANSAT is a small communications satellite intended for low earth orbit operations. The system is presently being designed and constructed by NPS's Space System Academic Group. The objectives of the satellite program are threefold:

1. To provide NPS students with educational hands-on experience in the design, development and operation of a low cost amateur satellite.
2. To provide the amateur radio community the opportunity to work with spread spectrum communications in a real time or store and forward mode. PANSAT is classified as an amateur platform. This allows PANSAT legitimate access to the amateur UHF frequency band for communications, experimentation and telemetry.
3. To provide a space-based platform from which NPS faculty and students can conduct small on-orbit experiments which conform to weight, space and power restrictions.

Figure 1 is a pictorial representation of PANSAT's objectives [Ref. 1].

The specific objectives of this thesis are to: (1) List the options which are available when licensing a satellite and to provide guidance as to the actions required to be undertaken to complete the process; and (2) Present topics which should be addressed when designing satellite systems, using PANSAT as a guideline.

The discussion of design considerations for PANSAT's systems are separated into two sets, the spacecraft bus and its payload. The spacecraft's bus is comprised of the computer, electrical power, structure and thermal control systems. PANSAT's payload consists of the communications system and the experimental systems, currently made up of a solar cell experiment with other possible experiments being discussed. PANSAT is a simple satellite which weighs approximately 150 lbs. As such, there is no attitude control, propulsion or active thermal control systems. The spacecraft will randomly tumble after its ejection from the Get-Away-Special (GAS) canister on a future shuttle flight. Because there is no attitude control, the communications antenna is isotropic.

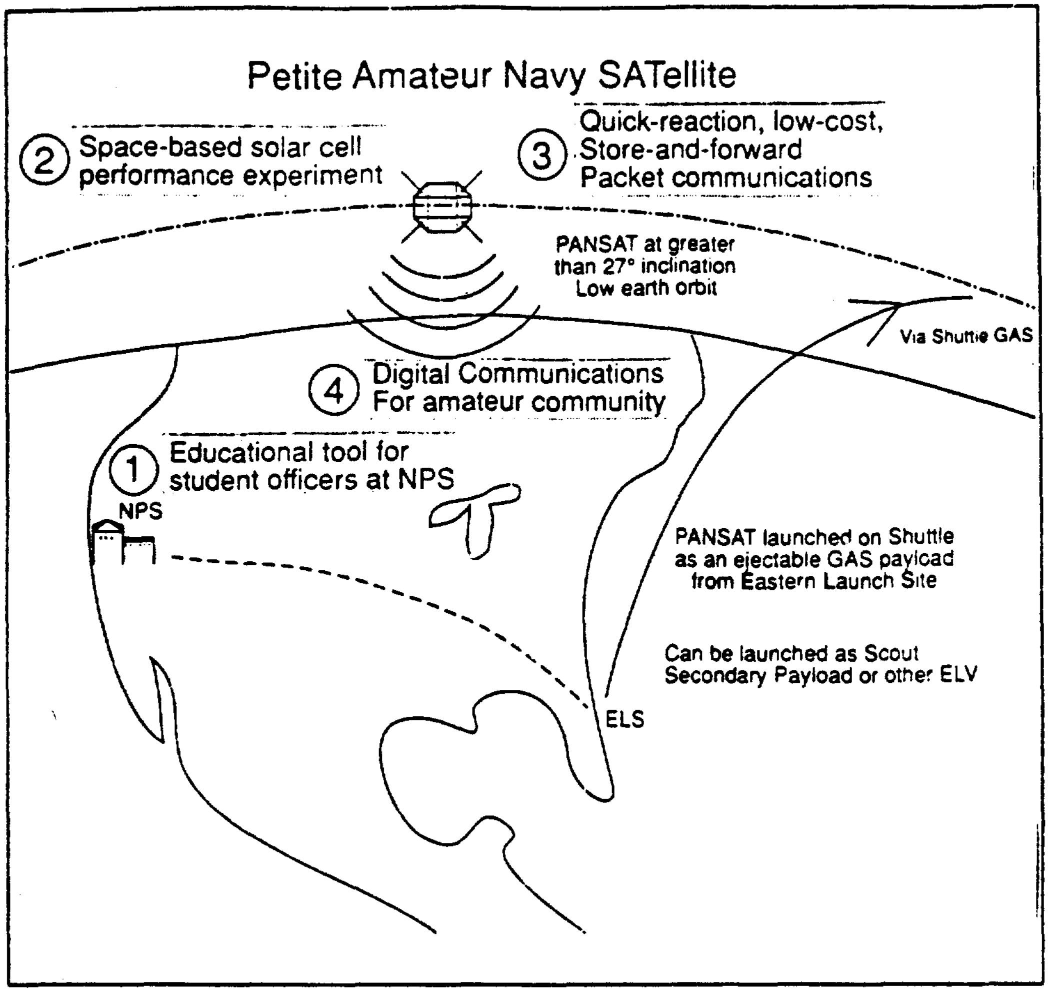
Petite Amateur Navy SATellite
② Space-based solar cell performance experiment
③ Quick-reaction, low-cost, Store-and-forward Packet communications
PANSAT at greater than 27° inclination Low earth orbit
Via Shuttle GAS
④ Digital Communications For amateur community
① Educational tool for student officers at NPS
NPS
PANSAT launched on Shuttle as an ejectable GAS payload from Eastern Launch Site
Can be launched as Scout Secondary Payload or other ELV
ELS

Figure 1. **PANSAT objectives**

The modulation of the communications signal is accomplished using Bi-Phase-Shift-Key (BPSK) direct sequence spread spectrum. The design life for the satellite is two years. PANSAT's estimated cost is $500,000 to $800,000. Although PANSAT is designed for a GAS canister launch, the possibility of other launch vehicles, such as Ariane, is not ruled out. The intended orbital altitude is 480 km at an inclination of 28.5°. Figure 2 shows PANSAT's configuration [Ref. 1].

To understand the processes involved with licensing a satellite, specific descriptions of the organizations involved, namely the Federal Communications Commission (FCC),

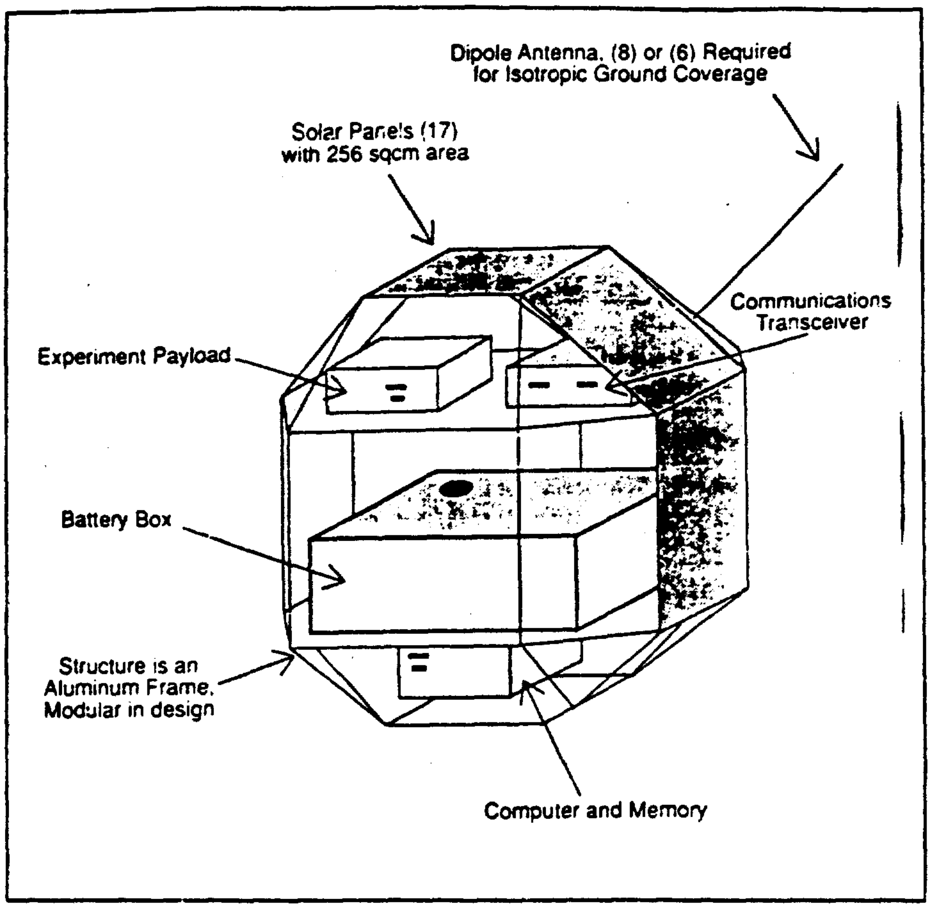
Dipole Antenna, (8) or (6) Required for Isotropic Ground Coverage
Solar Panels (17) with 256 sqcm area
Communications Transceiver
Experiment Payload
Battery Box
Structure is an Aluminum Frame, Modular in design
Computer and Memory

Figure 2. **PANSAT configuration**

National Telecommunications and Information Administration (NTIA) and the International Telecommunications Union (ITU), are included in the thesis. There are three licensing methods available to a satellite such as PANSAT. They are through amateur, governmental or experimental channels. Each method is discussed in detail, to include their respective advantages and drawbacks. This study provides guidelines for actions required to license and contains copies of the appropriate forms to complete.

II. GENERAL DESIGN CONSIDERATIONS FOR SATELLITES

This chapter discusses some of the support activities required when constructing a satellite and presents some general design considerations which would apply to the design of any type of spacecraft.

A. SUPPORT ACTIVITIES

The development and construction of a satellite can be a very complex process. Many perceive building a satellite as simply putting together technical components such that they form a working unit. The satellite is the end product of a massive effort by many people performing widely varying and seemingly unrelated tasks. It is into these supporting tasks that most of the work effort must go in order to realize the final operational flight unit. As an example of the supporting activities which are required to construct a satellite, the following is a partial list of such activities needed to build and operate a Radio Amateur Satellite Corporation (AMSAT) Orbiting Satellite Carrying Amateur Radio (OSCAR) satellite [Ref. 2: p. 13-1]:

1. Design of flight hardware.
2. Construction of flight hardware.
3. Testing of flight hardware.
4. Finished drafting.
5. Interfacing with launch agency.
    a. Provide documentation related to satellite-rocket interface.
    b. Provide safety related documentation.
6. Identifying and procuring future launches.
7. Construction management.
    a. Parts procurement.
    b. Arrange overall timetable and deadlines.
    c. Monitor progress of all subgroups.
    d. Allocating available resources (financial and human).

    e. Locating volunteers with special expertise.

8. Create launch information nets.
9. Provide user information.
    a. "Orbit" magazine production.
    b. Amateur Satellite Report newsletter production.
    c. Weekly AMSAT nets and information broadcasts via satellite.
    d. Respond to requests for information.
    e. Produce information programs (slide shows, videotapes).
    f. Facilitating magazine article and book production.
    g. Supporting educational programs.
10. Fund raising.
11. Coordination with international AMSAT affiliates.
12. Technical studies focusing on future spacecraft design.
13. Launch operations.
    a. Travel to launch site.
    b. Ship satellite to launch site.
    c. Connect satellite to launch vehicle.
    d. Final checks.
14. Create command station network.
15. Miscellaneous needs.
    a. Insurance?
    b. Licensing.
    c. Procurement contracts.
    d. Corporation papers.
16. Financial management.
    a. Overseeing record keeping.
    b. Auditing as required.
    c. Estimate future needs and cash-flow situation.
17. Maintain historical records.
    a. Telemetry and general.
18. Construction of test equipment and special test facilities.

As seen from this partial list, satellite production can get very involved. These are only some of the support activities required to produce an amateur satellite. By their very nature, amateur beauracratic requirements are fewer than for a commercial or military satellite. With a commercial or military satellite, additions to the above list would far outpace any subtractions.

B. DESIGN CONSIDERATIONS

The design of a satellite is a complex and always changing process. So what are the general design considerations to think about? The first requirement is to decide what the spacecraft is supposed to do. What is its mission? Agrawal lists six requirements a spacecraft must meet to support the mission [Ref. 3 : p. 31]:

1. Provide support to equipment in a layout that minimizes signal losses and interconnections.
2. Provide the required electrical power within specified voltage tolerances.
3. Provide temperature control within the limits imposed by satellite equipment.
4. Keep the spacecraft attitude within allowable limits.
5. Provide telemetry and command services to permit ground monitoring.
6. Provide support to the total mass with adequate stiffness, alignment, and dimensional stability.

Once the mission is established, some of the general design considerations to be addressed are performance, component availability, safety, cost effectiveness, affordability, physical limitations, mission requirements and reliability. See figure 3 [Ref. 4: pp. 75-85]. The remainder of this chapter addresses each of these general design considerations in greater detail.

Once the spacecraft's mission has been determined, a specific set of mission requirements are compiled. Mission requirements are simply a more detailed explanation of the general mission. Details such as orbital location, power output, bit rate, frequency band, user capacity and other related factors should be included as mission requirements. Based upon these required capabilities, an outline is produced that will be filled in by specific system designs.

Performance is a measure of the spacecraft's ability to complete its mission effectively. Is the mission accomplished with ease or is the reaction time too slow? Performance is mainly determined by the quality of the components and how they are interfaced with each other. The amount of money spent on the technology has a direct effect on performance.

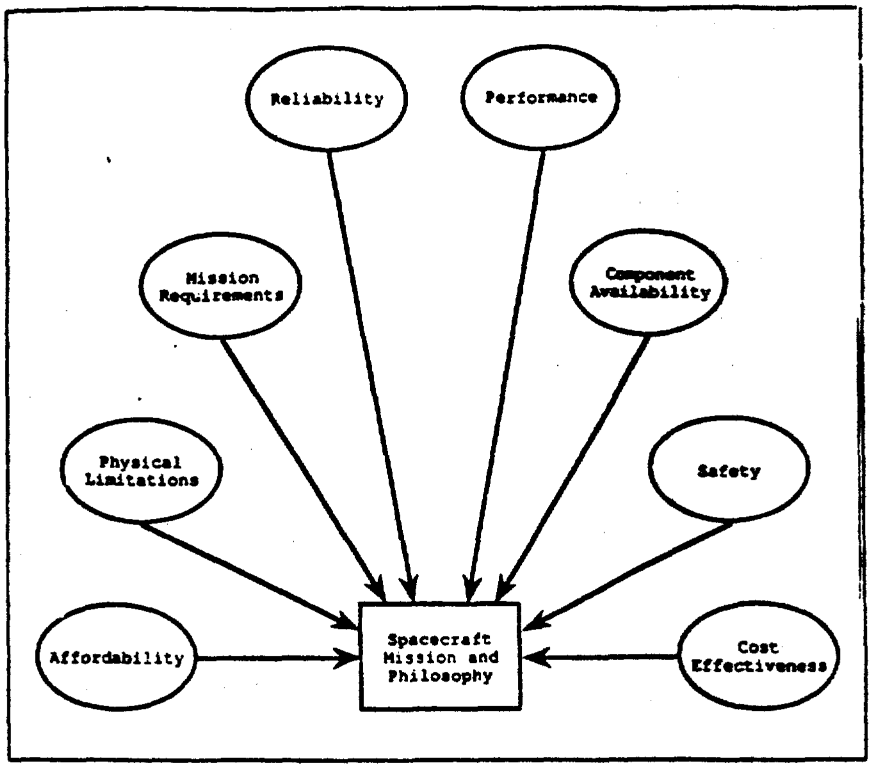

Figure 3. Satellite design considerations

The physical limitations of a satellite include its size, shape and weight restrictions. Physical limitations are mostly a function of the launch vehicle to be used. The plan for PANSAT is to use a Get-Away-Special (GAS) canister on the space shuttle, so PANSAT's physical dimensions are restricted to what can fit inside a GAS canister providing the weight and safety restrictions are met, as specified in the *Get-Away-Special Payloads Safety Manuel.* [Ref. 5]

Availability is a measure of the effort required to obtain a desired component. How much lead time is required when procuring a desired component to ensure that it will be on hand when the installation time arrives? With some satellite systems, components are purchased before the first unit of that component series has even been built. This practice is done to keep the system updated with the most current technology. A major problem can occur using this procurement method if there is a delay in the component construction program. The component delay pushes back the satellite completion date, all because of the availability consideration.

Reliability measures the expectation that a system will perform its function effectively over a certain period of time. This consideration can be quantified as Mean-Time-Between-Failure (MTBF). Again, the money invested affects system reliability. Were the satellite to be constructed using the cheapest parts available, chances are that the satellite would not be very reliable. Conversely, to make the satellite extremely reliable, the most expensive components should be used and every aspect of the system should be redundant. A problem with the second route of construction is that the satellite would certainly overrun its budget constraint. The mission of the satellite must be considered to determine how reliable the spacecraft needs to be. A spacecraft carrying men, such as the shuttle, needs to be more reliable than a disposable communications satellite such as CHEAPSAT. The mission determines the middle ground extent of reliability required. The best way to achieve a high state of reliability is through testing:

> No system can achieve its purpose more reliably than its least reliable component. For this reason it becomes the job of the engineer to develop hardware that is reliable and economical....Testing is far and away the most important ingredient in the development of reliable hardware. Testing should be carried out during every phase of the development. Time utilized in test programs is worth its weight in reliability percentages. [Ref. 6: pp. 155-156]

The total system reliability is a product of all the individual component reliabilities. If each component had a reliability of 0.999 and there were 100 components in the satellite, then the satellite's overall reliability would be 0.999^{100} or about 90%. To further increase reliability, redundancy is utilized, but this increases both satellite cost and weight. [Ref. 4: p. 98]

Cost effectiveness is another important design consideration which measures how well money is spent on a satellite. In the world of tightening budgets, when building satellites, one cannot adopt the attitude of creating the best satellite at any cost. Many values such as worth, probability of success, utility, effectiveness and total cost must be weighed to produce a cost-effective satellite design [Ref. 4: p. 80]. These values can be defined as follows:

> Worth is a composite measure of multiple program objectives and the degree to which these objectives are met within the assumed structure of the program being analyzed. Worth may be a decaying function of time in the case of a satellite which is constantly returning data. Probability of success is defined as the probability that all required subsystems are functioning properly at a given time. Utility means usefulness in the sense of satisfying a need. It is considered to be the product of worth and the probability of success. Effectiveness is considered equivalent to utility. Cost requires little definition; it may be categorized as consumption of physical resources, employment of human resources, and dissipation of time. [Ref. 7: p. 6]

Going back to the space shuttle versus CHEAPSAT example, the shuttle needs to use top of the line equipment, based upon its reusable manned mission. It is more cost effective for CHEAPSAT to use inexpensive components, due to its relatively short design life.

Affordability is also an important design constraint. Affordability addresses the question; Will the user be able to purchase the satellite system at the given price based upon their financial resources and need for the satellite? Boyd, in his thesis, categorized satellite costs into four groups: Bargain (< $1 million), Low Cost ($1-$10 million), Medium Cost ($10-$100 million) and High Cost (> $100 million). PANSAT falls into the 'Bargain' group, as illustrated in figure 4. [Ref. 4: p. 78]

The final design constraint considered in this chapter is safety. Safety is making sure that nobody is injured, on the ground or in space, and that the launch vehicle is not damaged as a result of the satellite. Since PANSAT is designed to fly in a GAS canister on the shuttle, safety is the most important consideration. All of the previously mentioned design constraints can be tampered with, ie. sacrifice some reliability for affordability, but safety is a fixed quantity and cannot be compromised.

C. STAGES OF SATELLITE DESIGN

Now that the general design considerations have been examined, satellite construction from a project manager viewpoint is looked at next. A basic six step method can be used to simplify the very complex satellite design process. The six steps are [Ref. 2: p. 13-2]:

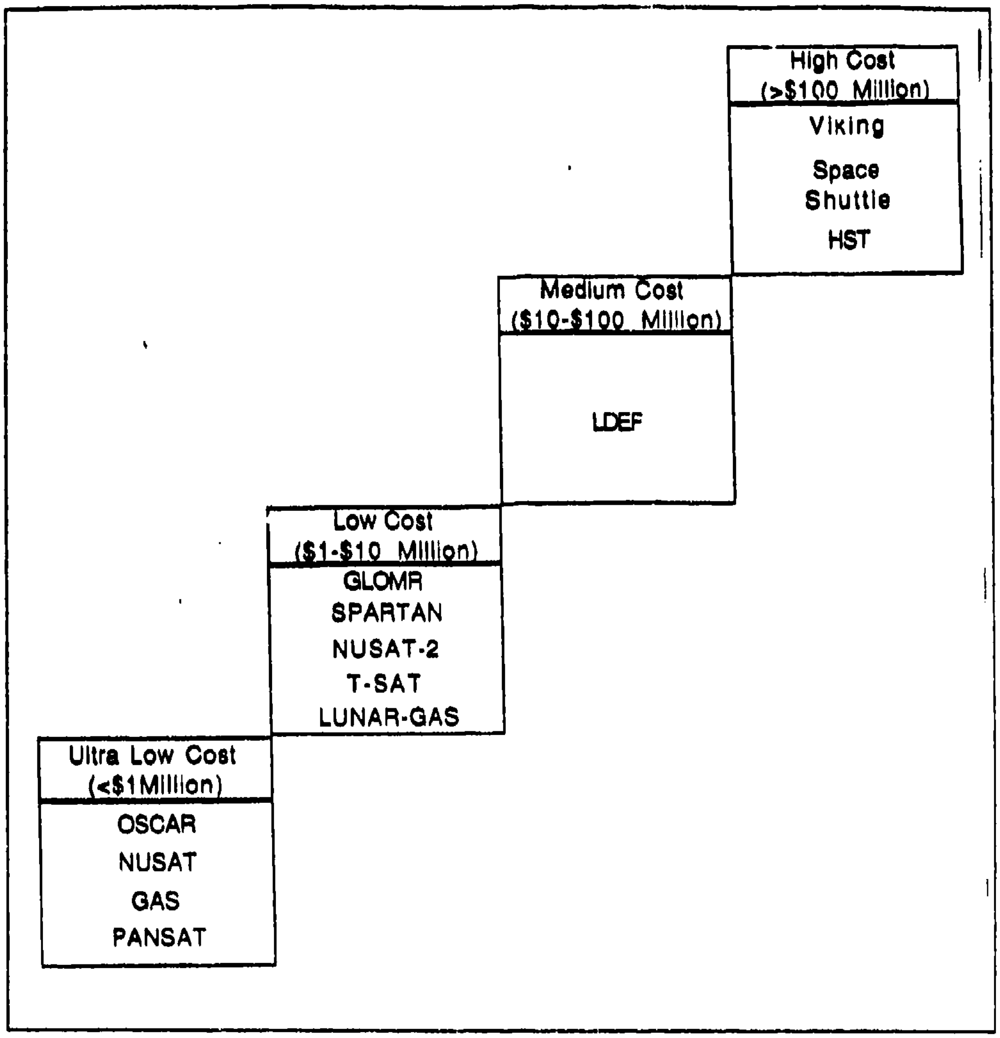

Figure 4. Satellite price groups

1. Preliminary design.
2. System specification.
3. Subsystem design and construction.
4. Integration and testing.
5. Launch operations.
6. Information dissemination and post-launch management.

Each of these stages are now examined in greater detail.

During the preliminary design stage, feasibility studies are performed to determine the approach to be used when designing the satellite. Elements such as launch opportunities, satellite mission, new technology and budget are considered. Agrawal gives the following reasons for feasibility studies being done during the conceptual design stage:

> To determine whether the mission performance requirements can be met within the mass and size constraints of the launch vehicle. The first step is to select a spacecraft configuration which provided a general arrangement of the subsystems. The mass and power requirements of the subsystems are estimated, based upon preliminary analysis and extrapolation of existing designs. [Ref. 3: p. 4]

Before terminating the preliminary design stage and progressing on to the next stage, the decision must be made to actually build the satellite. Once this decision is made, the system specification stage begins. The end product of the system specification stage are the specific subsystem requirements.

Once the subsystem requirements are defined, the next stage is the subsystem design and fabrication stage. In this stage, the individual satellite subsystems are designed, constructed, tested and modified as merited. Each subsystem of PANSAT is being designed and built by an individual or small group of thesis students at NPS. In general, with each of the systems, three versions of the system are constructed. First, an engineering development model, then a flight prototype and finally the actual flight unit are built. The engineering development model is the first attempt, using less expensive components. The flight unit is the actual system which is interfaced into the satellite. The flight unit uses the best and most reliable parts on-hand. Testing performed in this stage consists of temperature variation tests and over-and-under voltage tests. The purpose is to locate potential failure points and then modify the design to correct these weak spots.[Ref. 2: p. 13-2]

The satellite now passes into the integration and testing stage. Integration involves putting all the systems together such that a fully operational flight unit results. The testing portion of this stage puts the complete unit through vigorous tests to increase overall system reliability. Despite the high cost of testing, many designers believe this is the most important aspect of satellite development. Agrawal describes the testing process as follows [Ref. 3: p. 4]:

> The spacecraft design is qualified at the subsystem and system levels by conducting performance, thermal and vibrational tests. Units that do not meet the performance requirements during the tests are redesigned and retested. After successful completion of the qualification tests, the spacecraft design is finalized and the required number of spacecraft are fabricated. The flight spacecraft are subjected to acceptance tests to determine manufacturing and assembly defects.

During the integration and testing phase, the completed flight unit goes through a barrage of tests including stress tests, operational checks, electrical tests and RF compatibility tests. The satellite undergoes a burn-in period for the electrical components, in which the electronic systems operate at normal parameters and space temperatures, but under the earth's atmospheric pressure. Other stress tests include the environmental tests in which the satellite is operated in a vacuum and temperatures are varied over a wide range, roughly -20 °C to 60 °C. The purpose of the vacuum test is to (1) check for material sublimation; (2) test for corona discharge; and (3) check the interior thermal environment under operational conditions [Ref. 2: p. 13-3]. Another type of stress test is the vibrational test. During this test, vibrational launch conditions are simulated to ensure that the satellite will not fall apart during launch and orbital insertion.

A typical failure curve for mechanical and electrical components of a satellite is presented as figure 5 [Ref. 2: p. 13-3]. Besides searching for potential failure points on the satellite, testing is also pushing the satellite along that component failure curve until the satellite is past the initial failure hump, depicted in figure 5. By using high temperatures and overvoltages, the time scale is compressed such that the initial failure hump may be passed in a couple of weeks, vice months or years. [Ref. 2: p. 13-3]

After successfully completing all of these tests, the satellite moves into the next development stage, the launch operations. Launch operations include the transport of the satellite to the launch facility, attaching the satellite to the launch vehicle, performing final operational checks and the actual launch. Prior to actual launch operations, many supporting activities must have been performed in such areas as logistics, procurement, licensing, scheduling and coordination.

The project does not end with the launch. Information dissemination and post-launch management is the final phase. Ground stations must have been constructed to control the satellite. Information about the satellite must be passed on to the users. Satellite data must be collected and evaluated. Records are required to be maintained describing transmission parameters.

The time period from project inception to launch is highly variable. It depends on many factors such as budget constraints, human resource constraints, design complexity, quality of the initial design, workspace availability, ease of coordination, availability of testing facilities, launch opportunities and many others. For a project such as PANSAT. three to five years is a good estimate. As a comparative example of a similar type of spacecraft, figure 6 [Ref. 2: p. 13-2] shows a typical time frame for an AMSAT satellite project.

This chapter has provided several broad design considerations/constraints which need to be addressed throughout the design and construction of the spacecraft. Although PANSAT is a relatively simple satellite, the same design process is used and the same design considerations arise with any satellite construction project. PANSAT requires designs for the following systems:

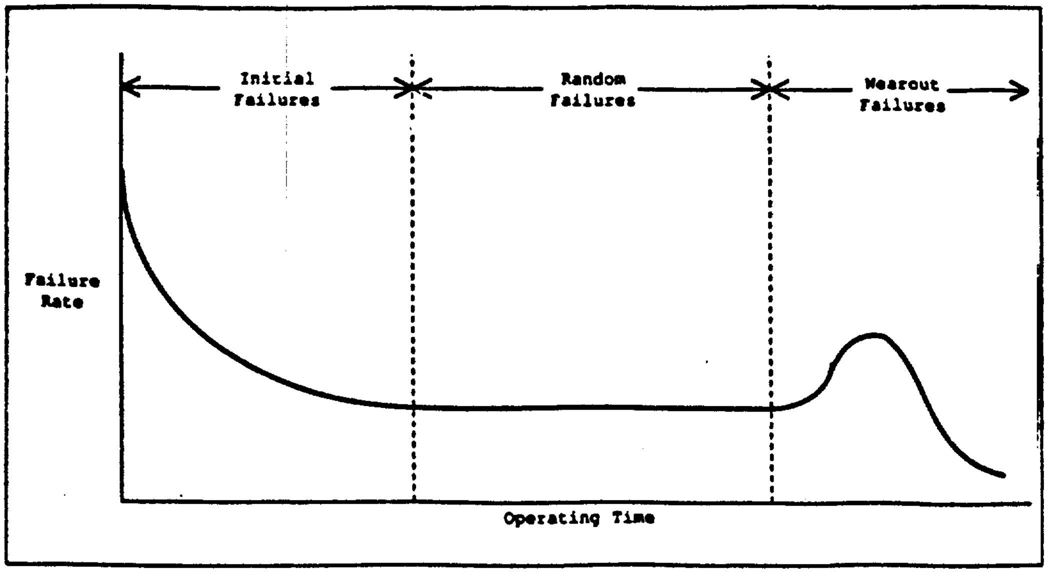

Figure 5. Component failure curve

1. Communications.
2. Experimental payload.
3. Computer.
4. Electrical power.
5. Structure.
6. Thermal (passive).

The next two chapters describe PANSAT's design for the aforementioned systems and address specific design considerations/constraints as they apply to this satellite.

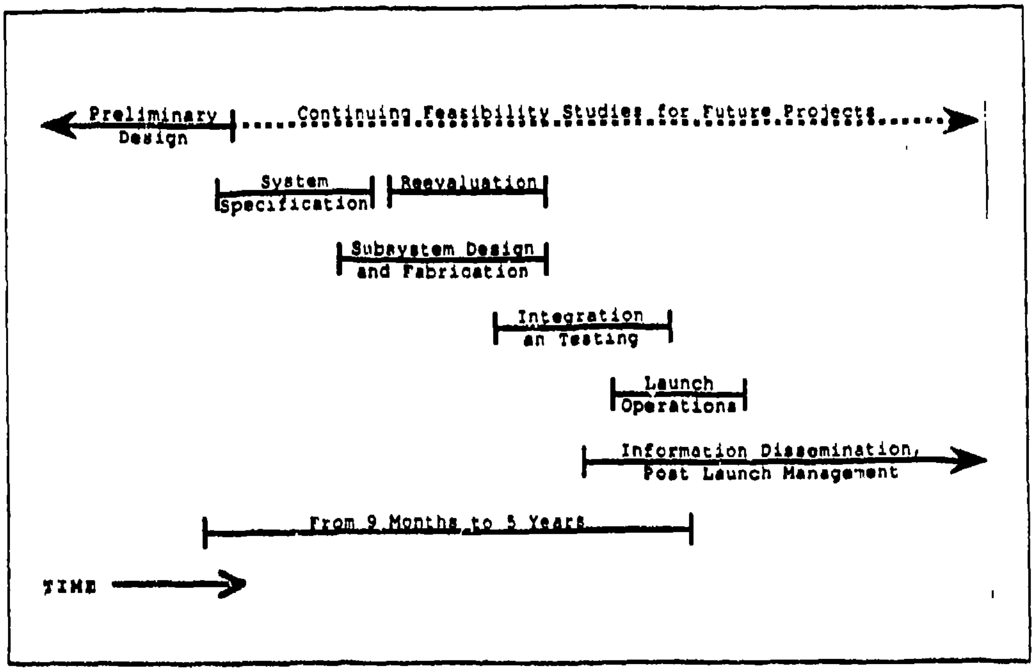
Preliminary Design
Continuing Feasibility Studies for Future Projects
System Specification
Reevaluation
Subsystem Design and Fabrication
Integration an Testing
Launch Operations
Information Dissemination, Post Launch Management
From 9 Months to 5 Years
TIME

Figure 6. Timeframe for AMSAT satellite construction

III. SPACECRAFT BUS DESIGN

PANSAT's bus consists of the structural, data processor and sequencer, thermal control, and electrical power systems. This chapter describes each system as currently designed and presents design considerations and constrictions for the individual systems.

A. STRUCTURAL SUBSYSTEM

A spacecraft's structural system is basically the frame which holds all the separate systems together. The structural system is composed of constructional hardware such as beams, plates, housings, brackets, braces, attachment fittings, structural fasteners an other metallic and nonmetallic elements which comprise the satellite's basic frame. Some of the functions of the structural system include: (1) to physically support the antennas, solar cells, and all internal components; (2) to provide protection for the on-board components during launch and when deployed; (3) to mate with the launch vehicle; and (4) to conduct thermal energy into and out of the satellite's interior. The shape of the satellite has a major effect on the electrical power system by influencing the efficiency of the solar cells. Spacecraft shape also effects the thermal control of a satellite, because shape is the dominant determinant of thermal equilibrium [Ref. 2: p. 12-7].

The structural hardware, through the course of its lifetime, absorbs energy from its environment in the form of stresses and heat. The absorbed energy can weaken the molecular structure the components, which could result in structural failure [Ref. 5: p. 163]. When structural failure occurs, the satellite, as an operational unit, is in severe jeopardy. It is important, therefore, that the structural system design be a sound one.

NPS had decided to design the satellite to be launched in a Get-Away-Special (GAS) canister during a space shuttle launch. A NASA photograph of a GAS canister, as

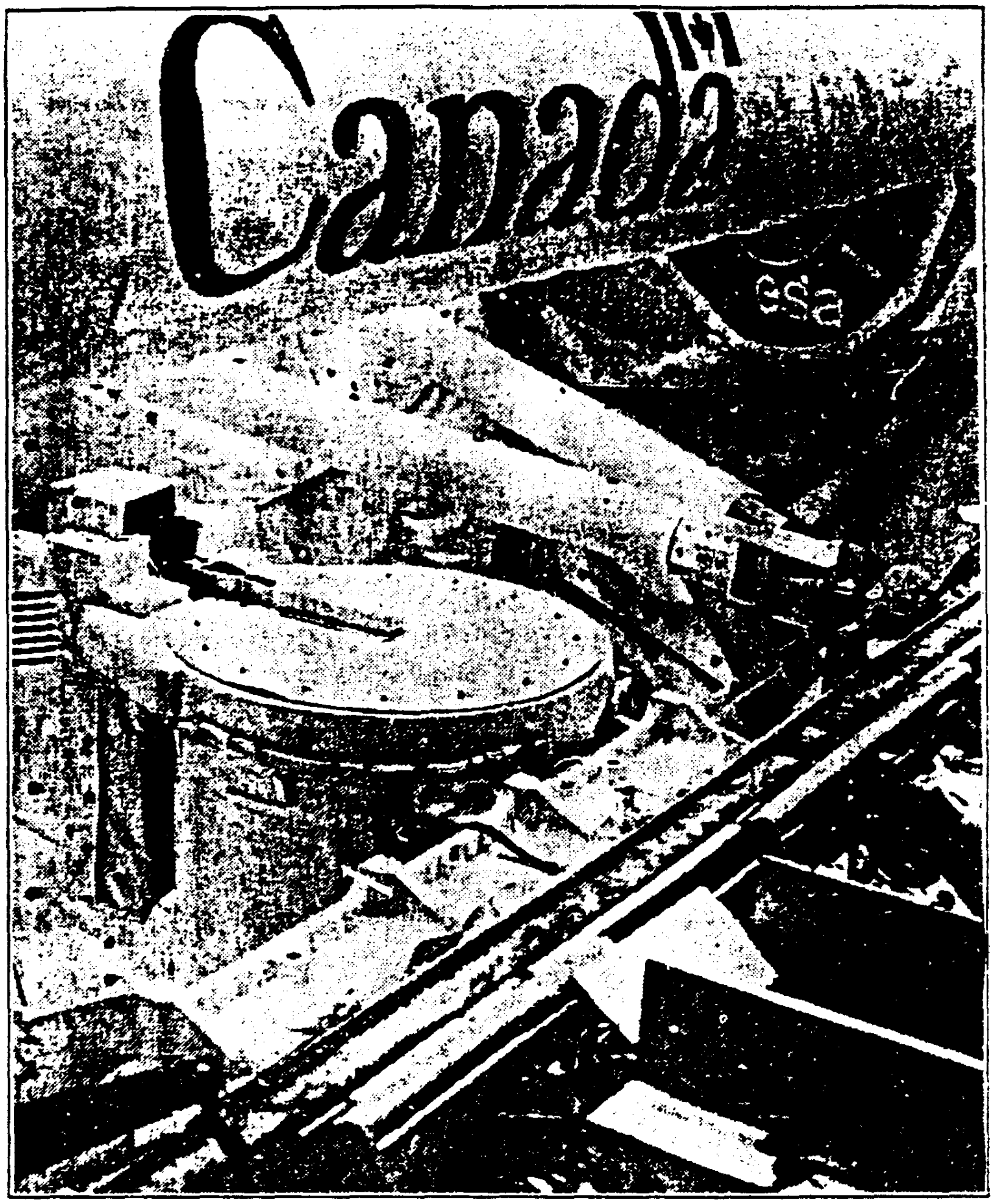

Figure 7. GAS canister mounted on space shuttle (NASA Photograph)

mounted in a space shuttle, is presented as figure 7. Since a shuttle flight is always a manned launch, safety considerations are much more intense than they would be for an unmanned rocket. By designing PANSAT for the more stringent GAS specifications, NPS has retained the option of utilizing an unmanned launch vehicle such as Ariane or Pegasus. Had NPS designed for an unmanned launch vehicle, PANSAT would not have met GAS specifications and the shuttle option would not exist. The main disadvantage of the shuttle option is the 28° inclination limitation (due to not launching over populated land masses) resulting from a Cape Kennedy launch. A launch of an unmanned vehicle from either Vandenberg Air Force Base in Lompoc, Ca. or Kourov, French Guyana, South America, could put PANSAT into an orbit with a much higher inclination. A higher inclination would be favorable to the solar cell experiment, and would increase the communication time window per orbital pass.

When designing to GAS specifications, the major concerns to the structural system are corrosion and failure under stress. The worry is that the failures will cause the structural elements to become projectiles. The two types of failures are brittle failures and elastic deformation. Brittle failures are more important for safety considerations. In metals, brittle failures are caused by hydrogen embrittlement, structural fatigue and stress corrosion. Stress corrosion is the most prevalent type of failure with aerospace vehicles [Ref. 5: p. 165]. An additional hazard is that some materials, when exposed to the space environment, give off gasses which may be damaging to surrounding equipment.

Before PANSAT can be approved for flight aboard the shuttle, detailed testing is required to verify the satellite's structural integrity. Required analysis includes a static stress analysis and a fundamental vibration frequency analysis [Ref. 5: p. 166]. GAS specifications require that PANSAT be able to withstand loads of ±9 g's of translational accelerations in the X-Y directions and ±15 g's in the Z direction [Ref. 5 p. A5]. The

GAS canister weight limit for a payload is 200 lbs [Ref. 5: p. 11]. These load and weight limits consider that the structure must be able to survive loads incurred during a crash landing. The present PANSAT structure design was analyzed using GIFTS interactive software. The finite element analysis showed that structural deflections remained in the linear regime. The modal frequency analysis was favorable as well. [Ref. 8: pp. 8-9]

When designing the satellite structural system, some of the specific design considerations to reduce stress concentration and avoid structural failure should be [Ref. 5: pp. 166-167]:

1. Use multiple load path structure when possible.
2. Make gradual changes in sections and symmetry of design.
3. Minimize the number of cutouts and discontinuities in primary elements.
4. Design for peak stress vice the average stress.
5. Avoid attachment of secondary brackets, fittings, handles, steps and hoses to high stress areas.
6. Avoid the use of rivets to carry repeated tensile loads.
7. Eliminate sharp edges for personnel safety and to reduce stress concentrations.
8. Select fasteners of sufficient size and proper material to carry design loads and impose proper pressure on joints through pretension.
9. Provide allowances for distortions and stresses resulting from thermal expansion and contraction of the space temperatures.

Additionally, the structural design must take into account the loads the satellite will incur during ground transportation and while being attached to the launch vehicle.

The choice of the material of which the structural elements are composed is an important decision. PANSAT's structural system is composed of aluminum 6061-T6 [Ref. 8: p. 8]. When using aluminum alloys, the metal should be either coated or chemically treated to reduce corrosion and pitting, or the metal should be an alloy with tempers having high resistance to stress-corrosion cracking [Ref. 5 : p. 167]. The environments in which the satellite will be found should also effect material selection. For a shuttle launch, the satellite will have to sit in the ocean salt-air of the Florida environment for some time. It will also have to endure chemicals used for cleaning and rinsing, inspection fluids, marking inks, crayons, lubricants, machining fluids and testing fluids, as there is a reasonable chance that the satellite will be exposed to these substances prior to launch [Ref. 5: pp. 168-169]. The design should also obviously consider the space environment.

Figure 8 shows the overall design for the structural system of PANSAT, including the placement of the communications module, the experimental payload, the battery packs, the computer and the power module [Ref. 1]. In three dimensions, PANSAT is shaped as a 26 sided polyhedron comprised of eighteen 3.307 inch by 7.244 inch square sides and eight 3.307 inches sided equilateral triangles. Central to the design are the two equipment plates, shown in figure 9 [Ref. 1]. The volume allowed by a GAS canister is roughly a satellite 19 inches in diameter and 19 inches in length. Hence, the diameter of PANSAT's equipment plates are limited to 18.62 inches. PANSAT will be positioned in a GAS canister as shown in figure 10 [Ref. 4: p. 114]. Figure 11 shows the dimensions for the two end blocks, which go on the top and bottom of the satellite when oriented as in figure 8 [Ref. 1]. The lower end plate is mated to the pusher plate of the ejection mechanism in the bottom of the GAS canister. Figure 12 shows the dimension for one of eight diagonal support structures [Ref. 1]. The support structures are the diagonal beams with the ends sheared at 45° in figure 8. Figure 13 depicts one of the satellite's four plate supports [Ref. 1]. In figure 8, the plate support is the plate in the center of the satellite. The communications module and experimental payload sit on the radially outward face of the upper equipment plate. The computer and power conditioning module are located on the outward side of the lower equipment plate. Two dipole antennas are mounted between opposite diagonal support structures. Most of the exterior surface of the structure is covered with solar cells.

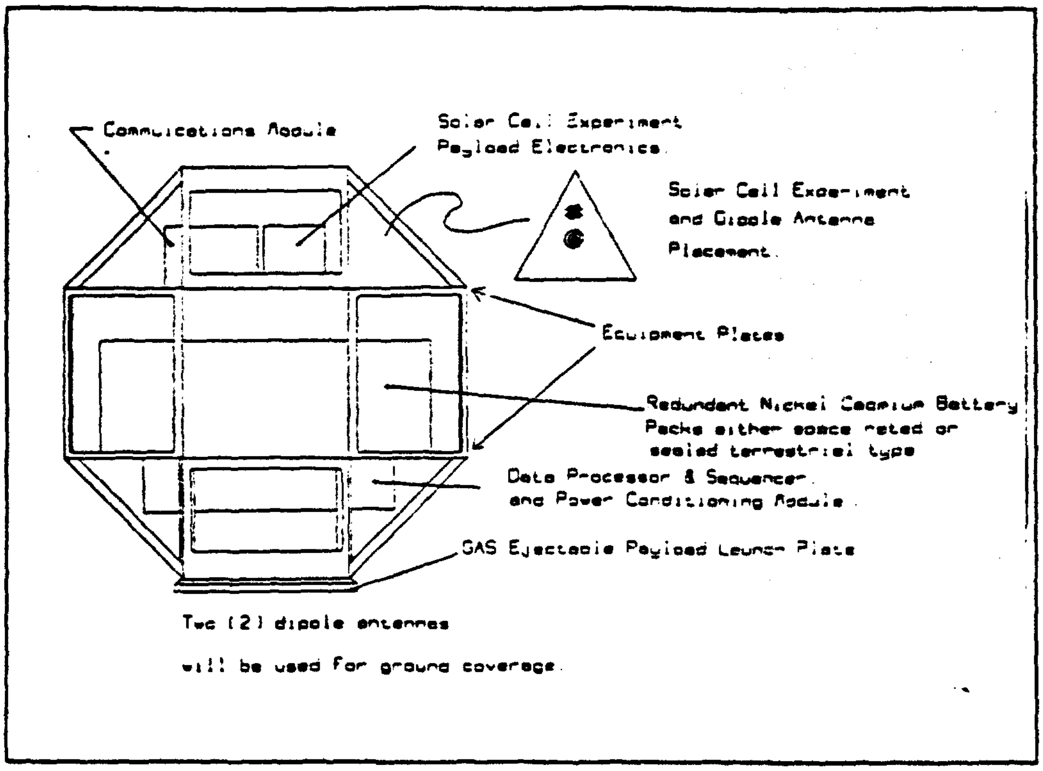
Communications Module
Solar Cell Experiment
Payload Electronics.
Solar Cell Experiment
and Dipole Antenna
Placement.
Equipment Plates
Redundant Nickel Cadmium Battery
Packs either space rated or
sealed terrestrial type
Data Processor & Sequencer.
and Power Conditioning Module.
GAS Ejectable Payload Launch Plate
Two (2) dipole antennas
will be used for ground coverage.

Figure 8. PANSAT structural configuration

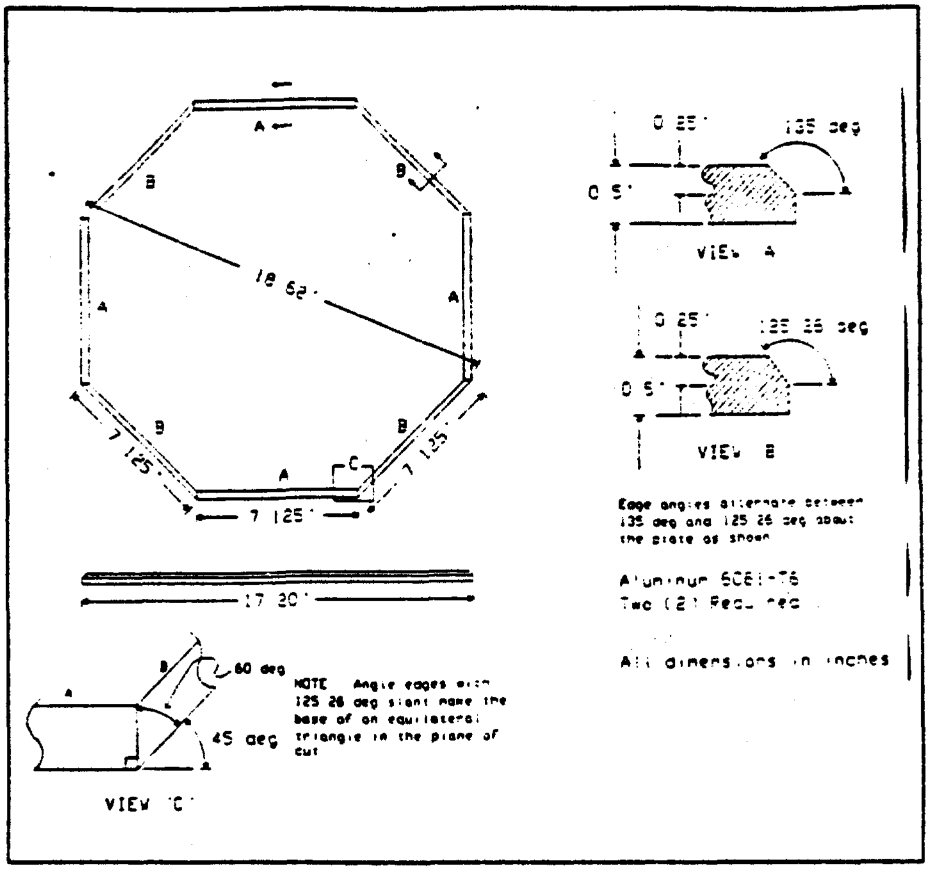
A
B
B
A
A
18 62
B
B
7 125
A
C
7 125
7 125
17 20
0 25
135 deg
0 5
VIEW A
0 25
125 26 deg
0 5
VIEW B
Edge angles alternate between 135 deg and 125 26 deg about the plate as shown
Aluminum 6061-T6
Two (2) Required
All dimensions in inches
A
B
60 deg
45 deg
NOTE Angle edges with 125 26 deg slant make the base of an equilateral triangle in the plane of cut
VIEW C

Figure 9. PANSAT equipment plates

Each of PANSAT's systems has been designed as a module. This makes it easier to test equipment as a separate system versus an integrated unit. It also simplifies the design and construction of the satellite. The polyhedronal structure, which is built around the two equipment plates, is a semi-monocoque structure. This type of structure is known for being structurally sturdy. It also maximizes the area which can be utilized for the placement of solar cells. Additionally, it is a good design from the thermal equilibrium viewpoint, a good characteristic to have for a tumbling satellite with only passive thermal control measures. Computer models of this structure have met GAS specifications, however, the actual flight unit has not yet been constructed. When it is completed, it will be required to pass a battery of tests before being approved as a shuttle payload.

B. DATA PROCESSOR AND SEQUENCER SUBSYSTEM

PANSAT's computer or Data Processor and Sequencer system (DP&S), is required to interface with all other systems of the satellite, to include the power, structure, communications, and experimental systems. Figure 14 provides a pictorial representation of the DP&S interfaces [Ref. 9: p. 10].

The DP&S system must support the missions of PANSAT as discussed in chapter one. The four general tasks assigned to the processor are communications, housekeeping, telemetry and command execution [Ref. 9: p. 16]. More specific functions which support the general tasks include [Ref. 9: p. 6]:

1. Respond to a ground station interrogation.
2. Receive messages from the communications system, store the massages and transmit the messages when ordered.
3. Maintain positive control of the satellite transmitter as required by FCC rules.
4. Control communications between the satellite and the ground stations.
5. Power management and battery charging.
6. Generate and format status messages.
7. Receive, decode and execute ground station commands.
8. Fault detection and recovery.
9. Update programming.
10. Store and dump telemetry data when requested.

In addition to the requirement to fulfil these tasks are the design issues of commonality, upward compatability and a real time clock. Commonality means using a

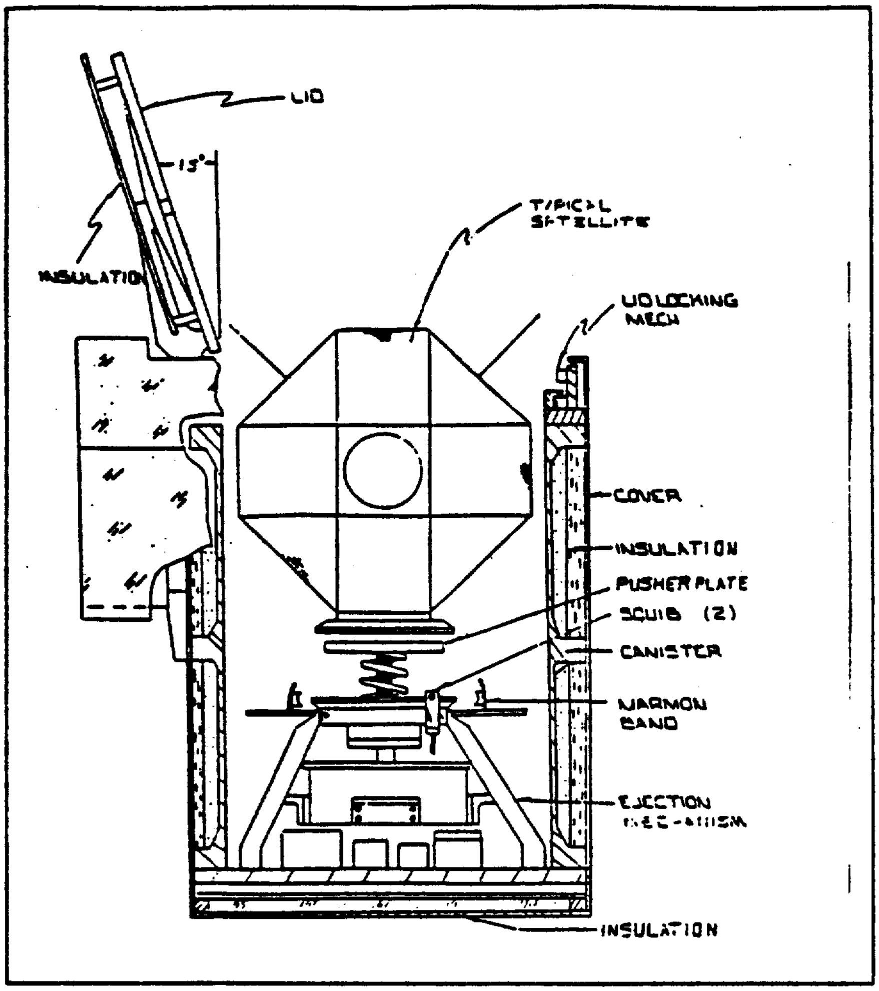

Figure 10. **PANSAT as positioned in GAS canister**

processor which is easily accessible and presently has a large number of users. Specifically, NPS should already possess and utilize this processor. Upward compatability means the DP&S system should be capable of being installed on a more complex satellite and perform effectively. PANSAT is merely a stepping stone for NPS to get involved with more advanced satellite systems. Effort and capital is conserved by designing a DP&S system for PANSAT which could be placed in the more complex ORION satellite, thus negating the need to design a new system from scratch. Finally, a real time

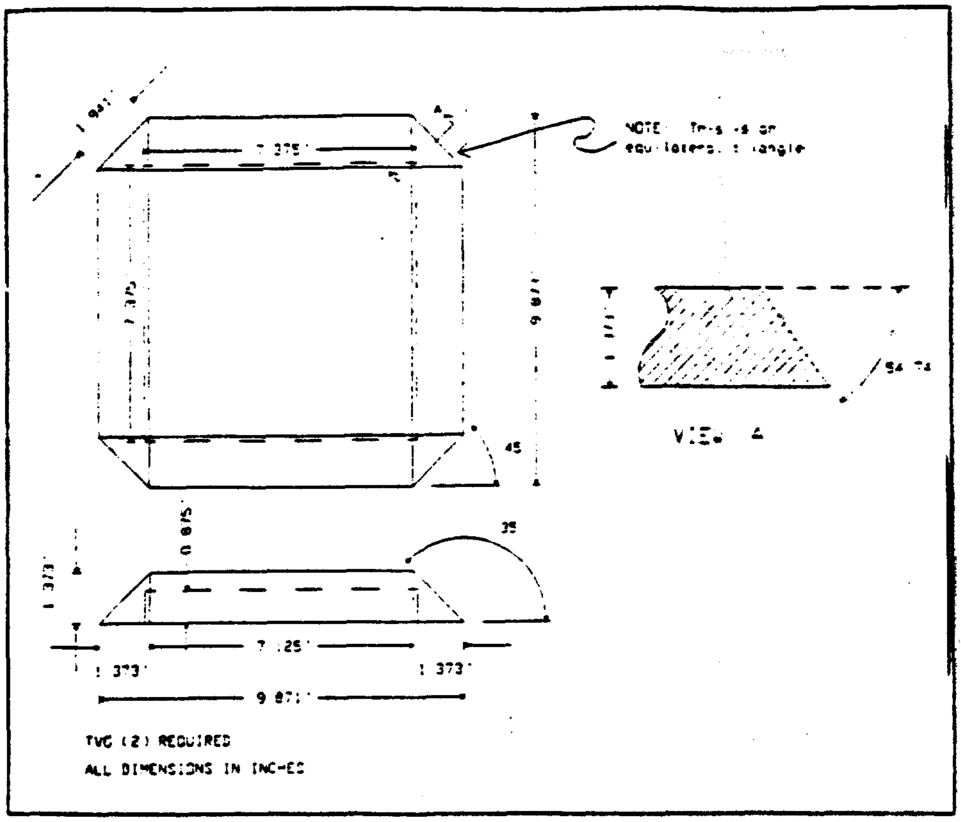

Figure 11. PANSAT end blocks

clock is required on-board to initiate prescheduled processor events at specific times. [Ref. 8: p. 3]

Besides the need to support PANSAT's many functions, several design constraints had to be considered before detailed DP&S design could commence. Consideration went into power constraints, size and volume constraints, budget constraints, vibrational durability constraints and environmental constraints.

PANSAT's power system consists of an array of 544 4 cm by 2 cm solar cells covering the satellite's external surface. The solar cells charge 12 2.1 volt, 5 amp-hr, lead-acid batteries. The batteries and solar cells provide a 12 volt unregulated bus. Most of the power is allotted to the communications system. The DP&S system is constrained by the amount of power allocated to it in the spacecraft's power budget. As the satellite

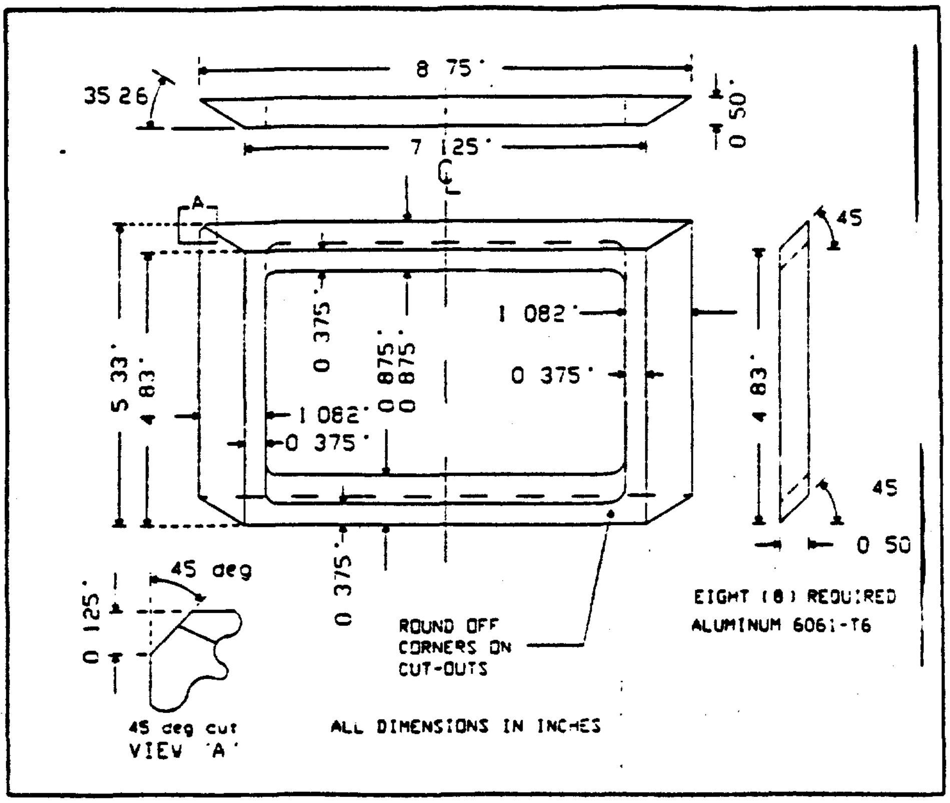

Figure 12. PANSAT diagonal supports

ages in orbit, the power system degrades. The result is reduced available power. The DP&S system should be designed to operate in degraded conditions.

PANSAT has to be a small satellite in order to be compatible with a GAS canister. Since PANSAT is so small, the volume allowed the DP&S system also must be restricted. Figure 15 shows the dimensional envelope to which PANSAT's processor is constricted. The weight constraint is not anticipated to be a problem.

The DP&S system must be designed to operate in the environment associated with a low-earth-orbit. The system must perform in a vacuum with temperatures ranging anywhere from -160°C to 100°C [Ref. 5: p. 65]. The satellite operates completely out of the earth's atmosphere and will absorb more solar radiation than if protected by the atmosphere. For this reason, and to afford additional protection should the satellite operate in the Van Allen radiation belts, it is desirable to use radiation hardened components in the DP&S system. Radiation hardened components also protect against

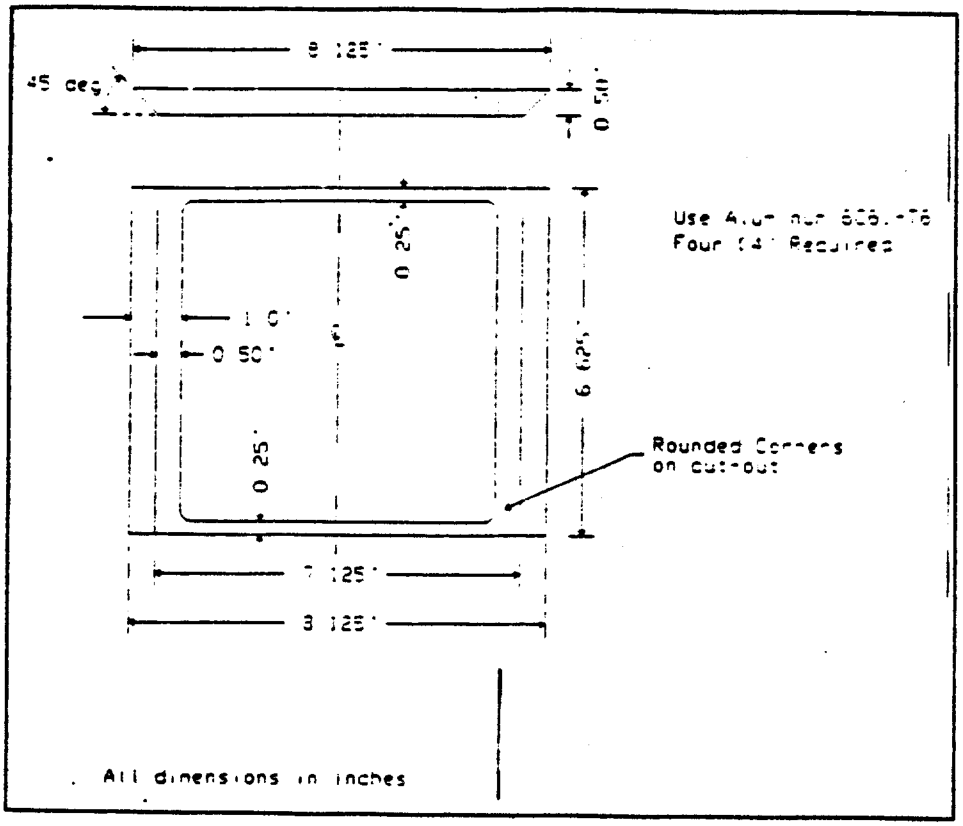

Figure 13. PANSAT plate supports

Single Event Upsets (SEUs), which are caused by energetic particles penetrating the satellite exterior and depositing energy into an interior circuit board chip, causing an electronic hiccup. An additional environmental constraint is geographical in nature. Because of the 28.5° inclination shuttle limitation, the satellite will have the ground station at NPS in line-of-sight for less than ten minutes per orbit. Data can only be exchanged during this limited time.

Because of the intended simplicity of PANSAT, no attitude control system is installed. The satellite tumbles throughout its lifetime. As a result, an omnidirectional antenna is used to ensure communications during the transmission window. The subsequent reduction in power efficiency, along with the restricted size, limit the possible number of transceivers to one. PANSAT is therefore limited to a single communications

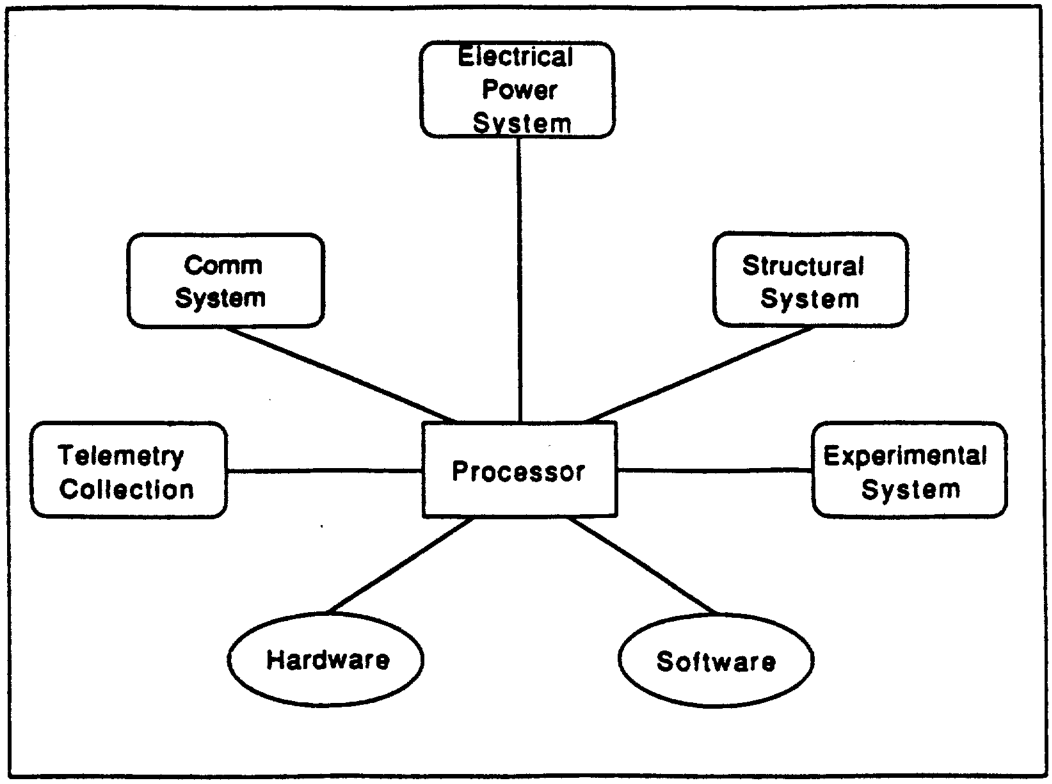

Figure 14. PANSAT DP&S interfaces

link. This restricted communications capability simplifies the DP&S hardware design, but complicates the required software [Ref. 9: p. 16].

Consideration of vibrational constraints means the DP&S system must be designed to withstand the high vibrations encountered during launch. Financial constraints limit PANSAT's overall budget to approximately $500,000 to $800,000.

The processor chosen is based on the Intel 8060 processor, also available in a radiation hardened version, the HARRIS 80C86RH processor. The AX.25 communications protocol is used to standardize the link for amateur digital communications. Implementation of the AX.25 protocol is done using a Zilog Z80C30 serial communications controller. The DP&S system has three different memory sections: fixed storage (PROM), vital RAM and bulk storage RAM. PROM holds the operating system kernel. Vital RAM holds the system's vital data. Bulk RAM holds the message and telemetry data. A watchdog timer, a 82C54RH programmable interval timer, is used to protect

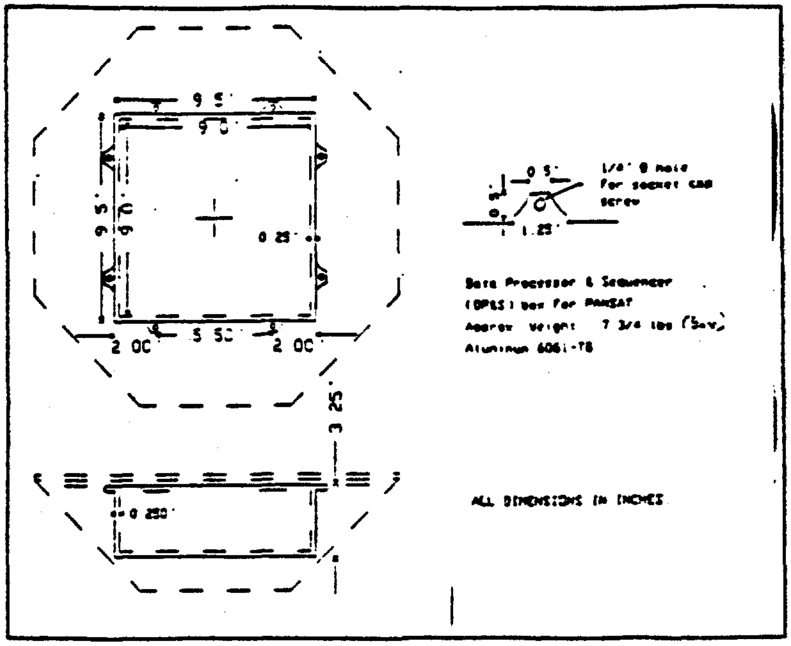

Figure 15. **PANSAT DP&S envelope**

against processor failure. Should the timer not be reset by the processor, and hence complete its countdown, it initializes the processor and secures control of the transmitter. Additional components include analog digital converters and parallel input output capability. [Ref. 8: p. 4-5] Figure 16 shows PANSAT's DP&S system design [Ref. 9: p. 29].

C. THERMAL CONTROL SYSTEM

PANSAT is a very simple satellite. In conjunction with its simple design, PANSAT utilizes only a passive thermal control system. As of this date, there is not yet a formal design for PANSAT's thermal control.

The purpose of a spacecraft's thermal control system is to regulate temperatures within the satellite. Thermal control is dependent upon the manipulation of the thermal balance equation. Incoming energy is equal to outgoing energy. The designer must take into account the various environments in which the satellite operates. This includes prelaunch, transfer orbit and final orbit. Once in space, important considerations include sun intensity, sun angle, periods of eclipse, the amount of internal heat generated by operating equipment, the satellite's orientation to the sun, the orbital parameters and,

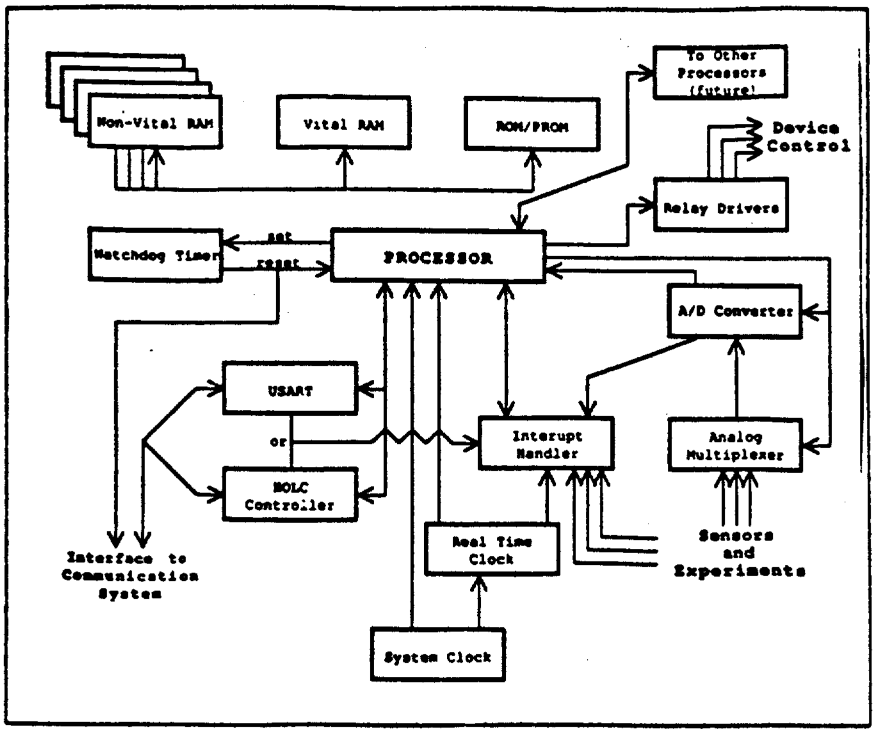

Figure 16. PANSAT DP&S design

for PANSAT, the tumbling rate. The objective of thermal control is to maintain the interior temperature of the satellite within a temperature range indicative of the equipment's optimal operating temperatures. The spacecraft cannot get too cold during eclipse, or too hot during vernal equinox, when solar intensity is a maximum. PANSAT will have to endure a worst case temperature range of -160°C to 100°C, which could be experienced while stored in the GAS canister in the shuttle cargo bay.

Passive thermal control maintains component temperatures within the desired temperature ranges without using any moving parts. In space there is no convection, so passive measures regulate temperatures by controlling radiative and conductive heat paths through the use of geometry and material composition. Some passive measures are thermal coatings, thermal insulations, heat sinks and phase changing materials. [Ref. 3: pp. 292-295]

The exterior surfaces of the satellite radiatively connect the spacecraft to space, the ultimate heat sink. Heat is generated from the spacecraft's interior to exterior through a combination of conductive and radiative paths. On the exterior, the two important surface parameters are the solar absorptance (α) and the surface emittance (ε). A low α and a high ε minimize solar input and maximize heat radiated into space. A combination of different coatings, resembling a chess board, may be used to get the desired effect. [Ref. 3: p. 295]

Thermal insulation between two areas reduces the rate at which heat flows from one area to the other. Some of the uses of thermal insulation are to [Ref. 3 : p. 296]:

1. Minimize heat flow to or from a component.
2. Reduce the amplitude of temperature fluctuations in components due to time-varying external radiative flux.
3. Minimize the temperature gradients in components caused by varying directions of incoming external radiative heat.

A heat sink is composed of a material with a large thermal capacity. The heat sink is placed in contact with the piece of equipment whose temperature needs to be regulated. As the equipment component generates heat, the thermal energy follows the conductive path into the heat sink. The heat sink dissipates the heat through other radiative or conductive paths. This keeps the temperature of the equipment component from getting too high. Heat sinks also work in reverse by preventing the equipment from getting too cold during eclipse. [Ref. 3: p. 297]

The thermal control subsystem for PANSAT most likely will use a combination of these techniques. Once the design is completed extensive testing should be done to ensure the passive measures maintain the temperatures within operational limits.

D. ELECTRICAL POWER SYSTEM

The purpose of the energy supply system of a satellite is to provide electrical power for all on-board systems, hence the title Electrical Power System (EPS). All the general design considerations discussed in chapter two, such as affordability and cost-effectiveness, apply to the EPS. Some types of solar cells alone would far surpass PANSAT's budget, so one can see how the general design considerations are important. A quantifiable ratio used to compare different power sources is efficiency. Efficiency can be measured as either the ratio of available electric power to weight, or as the ratio of available electric power to waste heat. With both ratios, the larger ratio denotes a desired higher efficiency. When attempting to design a simple, inexpensive, efficient, reliable and long-lived power supply, there are several problems associated with power production in space which must be addressed.

The first problem is the removal of waste heat. Power generation always produces waste heat. The waste heat must be removed from the spacecraft. As mentioned in the previous section, convective heat paths do not work in space. On the exterior of the spacecraft, convection is not very efficient, due to the lack of molecules surrounding the satellite. Radiation is the most economical method of heat dissipation. While conduction works well using radiators in contact with the heated equipment, a large weight and space penalty is payed, thus increasing launch costs. [Ref. 10: p. 4.1]

The second problem associated with power production in space is the near vacuum environment, which also contributed to the heat removal problem. Because of the vacuum, some additional problems which could be encountered are cold welding, outgassing, and leakage. Also some components of the EPS may require a pressurized environment. [Ref. 10: p. 4.1]

Should PANSAT operate at a higher orbit than anticipated, radiation could present another problem. Radiation is especially damaging to solar cells. Shielding may be required to protect the internal components from high energy particles, which result in SEUs. More weight penalty is incurred. The lack of gravity in space is another factor to consider. On earth, gravity is used to separate vapors from liquids during convective heat transfer. In space, gravity does not help the process and systems have to be designed to operate in any orientation, not in a "this end up" mode. Temperature variation must be considered. Battery efficiency decreases as the temperature drops, but the power output of solar cells increase with the same drop [Ref. 10: p. 4.2]. The battery operating range is from 0°C to 45°C, while the solar cells operate from -160°C to 100°C [Ref. 11: p. 13]. A temperature must be selected and maintained which maximizes the capabilities of both components. Finally, the EPS must be sturdy enough to survive the launch environment and still function properly.

The electric power system is vital to satellite operations. Without power, the satellite cannot function, the experiments will not work, and nobody would be able to communicate with it. The satellite would be an orbiting piece of useless aluminum. In most cases, the system which determines design life is the EPS. That means that the EPS generally fails first, with either the batteries or solar cells degrading before the other components. This is not likely to occur with PANSAT, since it will probably burn up entering the atmosphere, because of orbital decay, before a major component failure.

Presently, there are three categories of power supplies: nuclear, chemical and solar. Although nuclear systems possess a high available power to weight ratio, the enormous cost and obvious safety factors involved with such a power supply eliminate this type of power supply from consideration. Most satellites, to include PANSAT, use a combination of chemical and solar sources. Solar cells are the primary power source, with chemical batteries secondary. During a noneclipse period, the solar cells provide power to the satellite and charge the batteries. During eclipse, no power is produced by the solar cells and the batteries supply the bus power. At an orbital altitude of 480 km, PANSAT has a period of 94.2 minutes and an eclipse interval of 35.8 minutes. PANSAT has to operate on battery power for roughly 38% of its lifetime. Batteries are not practical as a primary power supply, due to their limited lifetime, but are ideal as a secondary source. They are reliable, low-cost, simple and readily available.

The use of solar power as the primary power source also makes sense. They are relatively low in cost for the power they produce. They generate little waste heat and produce satisfactory ratios of available power to weight. There are two methods of converting solar energy to electrical power: thermal and photovoltaic. Thermal solar conversion involves using mirrors to concentrate the solar rays into a container filled with high power density salts, such as aluminum florides, thus sequentially melting and freezing the salts as the satellite passes into and out of eclipse. Electrical power in obtained from the heat given off by the salts. This conversion method is still experimental. [Ref. 10 : pp. 4-5]

The most common solar conversion method uses the photovoltaic effect. PANSAT uses photovoltaic cells. The photovoltaic effect is the generation of voltage by photons incident upon a properly treated surface that lies near the junction of two layers of somewhat different materials. These cells are connected in series to provide a desired voltage. The resulting subunits are connected in parallel to supply the desire current. [Ref. 10: pp. 4-6]

To design PANSAT's EPS, all available factors were considered. In addition, certain assumptions had to be made, due to the parallel design efforts for the major systems. In general. it is always safer to use worst case assumptions. Some of the assumptions made in PANSAT's EPS design are [Ref. 11: pp. 12-15]:

1. An orbital altitude of 480 km.
2. An orbital period of 94.2 minutes.
3. An eclipse time of 35.8 minutes per orbit.
4. A two year design life.
5. A tumbling rate of 0.1 rad/sec favoring no particular axis.
6. Solar array operating temperatures from -160°C to +80°C.

7. Battery and electronic operating temperatures from 0°C to +45°C.
8. No heater is necessary.

PANSAT's EPS design consists of a photovoltaic silicon cell system. Components include the solar array, batteries, a battery charge regulator, and an instrument switching regulator in the form of DC to DC converters. The solar array is made of 17 panels, each of which hold 32 2 cm by 4 cm solar cells in series, generating a panel voltage of 15.5 volts at Beginning-Of-Life (BOL) and providing an unregulated bus voltage of 14.9 volts. The efficiency of the solar cells is 14.3%. Bus voltage is clamped at a minimum of 12 volts by two lead-acid batteries in parallel with the bus. Each battery has six 2.1 volt, 5 amp-hr lead-acid cells. The battery charge regulator (BCR) monitors the individual battery voltages, and provides a pulse modulated charge current alternatively to each battery. Power conditioning for the unregulated bus is provided by DC to DC converters with changes of voltage, regulation and protection. The entire system is capable of providing 18.3 watts of power . [Ref. 11: p. iv] Figure 17 shows a schematic of the system [Ref. 11: p. X]. Tables 1 and 2 show PANSAT's power budget and eclipse power requirements, respectively [Ref. 11: p 16].

Table 1. PANSAT POWER BUDGET

SATELLITE COMPONENT	NOMINAL POWER (W)	DUTY CYCLE (%/orbit)	AVERAGE POWER (W)	AVERAGE W-HR
Microprocessor	2.6	100.0	2.6	4.1
Transmitter	15.7	25.5	4.0	6.2
Receiver	2.0	100.0	2.0	3.1
BCR	1.0	62.0	0.6	0.9
ISR	0.5	100.0	0.5	0.8
Payload	0.5	62.0	0.3	0.5
Power Orbit	-	-	10.0	15.7
10% Margin	-	-	1.0	1.6
Total Power	-	-	11.0	17.3

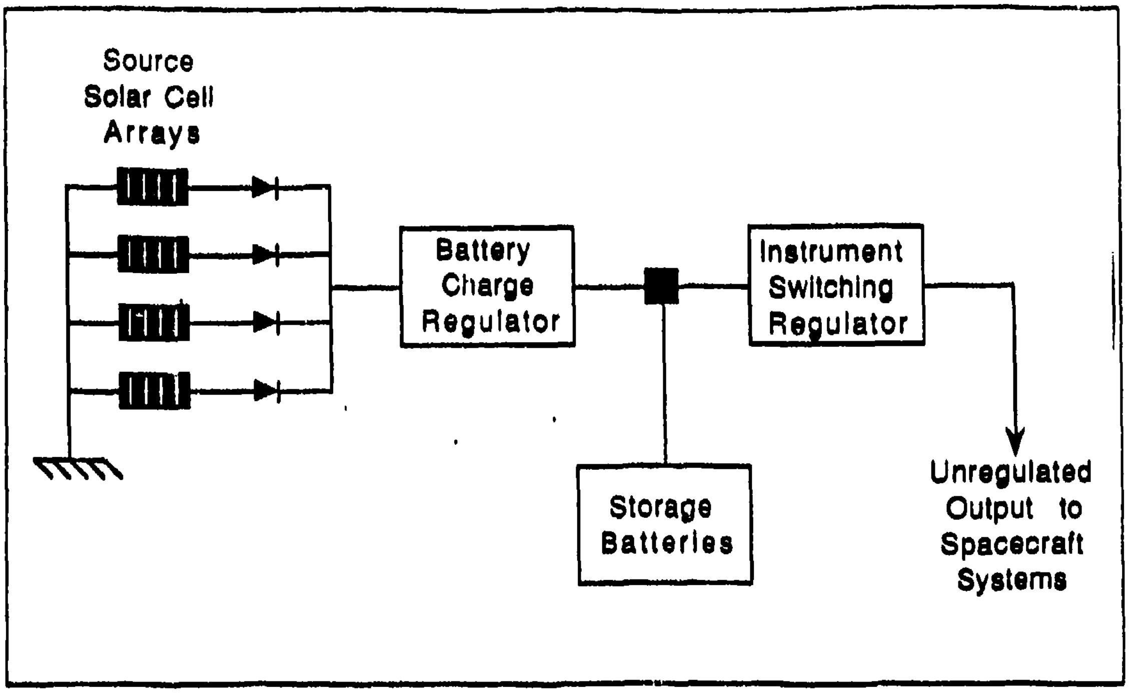

Figure 17. PANSAT EPS

Table 2. PANSAT ECLIPSE POWER REQUIREMENTS

SATELLITE COMPONENT	POWER (W) PER ECLIPSE	WATT-HR PER ECLIPSE
Microprocessor	2.6	1.6
Receiver	2.0	1.2
ISR	0.5	0.3
Total Power	5.1	3.1

IV. SPACECRAFT PAYLOAD

PANSAT's payload consists of the communications system and the experimental module. This chapter describes the individual systems and presents specific design considerations and constraints pertaining to both systems.

A. COMMUNICATIONS SYSTEM

While in the initial design stages of PANSAT, an important issue to be decided was the method of communication. What would the communications system consist of? A preliminary link analysis had to be performed. A transmission frequency and mode of transmission had to be chosen. Keeping in mind that PANSAT is an amateur platform, the frequency would have to be high enough to penetrate the atmosphere relatively unattenuated, but low enough that antennas and transmission lines would not have to be so critical in parameter dimensions as to make the satellite difficult to use.

It was eventually decided that PANSAT would carry a BPSK direct sequence spread spectrum half-duplex communications package. The single carrier frequency is located in the UHF amateur band at 437.25 MHz. The signal has a 1.2 kHz bandwidth which is spread out to almost 1 MHz. The bit rate is 1200 bps.

When using spread spectrum communications, interference is expected because many messages may be sent over the same frequency band at the same time. This interference is kept to a minimal level, conducive to good operations, by spreading the power from each signal evenly over a large bandwidth. The modulating signal is virtually random, while the transmissions carry a message with a unique signature which can be recognized and retrieved. To meet these requirements, each message is scrambled by means of a pseudo-random sequence. Receiving stations must be able to generate the pseudo-random sequence and synchronize it with the transmission to be capable of decoding the signal. The method of direct sequence spread spectrum combines a train of pseudo-random pulses with the message signal. The pulse repetition rate of the pseudo-random signal must be sufficiently high to spread the signal over the entire bandwidth, 960 kHz in this case. One message bit is combined with a train of several, possibly hundreds, pseudo-random bits called 'chips.' The receiving station, which knows the pseudo-random sequence, generates a chip train. The received signal, consisting of the chip train and the message bits, is compared with the generated chip train. The message bits are picked out of the received signal, and the unscrambled signal is now understandable. This process is known as coherent detection. All other transmissions, which are combined with different pseudo-random sequences, appear as noise. The signal-to-noise ratio is proportional to the number of chips per bit. Two advantages of spread spectrum communications are that they are interference or jam resistant and they are secure because receiving stations require the pseudo-random code. [Ref. 12: pp. 221-222]

NPS chose a spread spectrum design for two reasons. The first is that this type of communications is operationally used in the fleet. NPS is a Navy school, and as such, students here should be exposed to systems resembling those used in the fleet. Several naval operational nets utilize spread spectrum communications, including the Joint Tactical Information Data System (JTIDS), for the protection offered by the two previously listed advantages. The second reason is that currently there are no amateur satellites capable of spread spectrum communications. PANSAT would introduce this communications type to the amateur community. Given the caliber of the amateur operators, many of whom are engineers for major corporations, advances in this technology are likely to follow.

The most important design consideration for a communications system is its mission. PANSAT is able to function in one of two different modes. The first mode is as a transponder capable of storing and forwarding messages. The second mode enables PANSAT to retrieve and downlink experimental and telemetry data. The first mode is available to all amateur operators, while the second is restricted to NPS usage. A standard AX.25 packet protocol is used within which the message substance and message address are loaded. If the address is that of PANSAT's Telemetry, Tracking and Control System (TT&C), then the satellite operates in the second mode and responds to the commands contained in the message substance. For any other address, the satellite operates in the simple transponder mode and forwards the message. [Ref. 13: p. 4]

As with all of PANSAT's systems, a design constraint is the available power. Also the size and weight restrictions must be met. Power restrictions for the communications system are shown in table 1 of the previous chapter, which contains PANSAT's power budget. For PANSAT, the weight of the communications package is not anticipated to be a restricting factor. Figure 18 shows the dimensional envelope allotted the communications system and the experimental payload jointly [Ref. 1].

Although spread spectrum communications can be complicated, an attempt was made to keep it as simple as possible. For example, a single channel is used for uplink and downlink, which eliminated the need for additional frequency conversion hardware [Ref. 13: p. 14]. Choosing to use the simplest type of correlator available is another example.

The availability of the frequency spectrum is a constraint which is addressed in detail in the second half of this thesis. Federal and international agencies are responsible for regulating the usage of the electromagnetic spectrum for the purpose of reducing the existence of harmful interference among users. Desired frequency channels must be applied for through the proper agencies. PANSAT uses the UHF amateur band from 435 to 438 MHz. There is only a 3 MHz zone in the UHF spectrum available to the amateur community. Therefore, PANSAT has a bandwidth restriction. This is important in

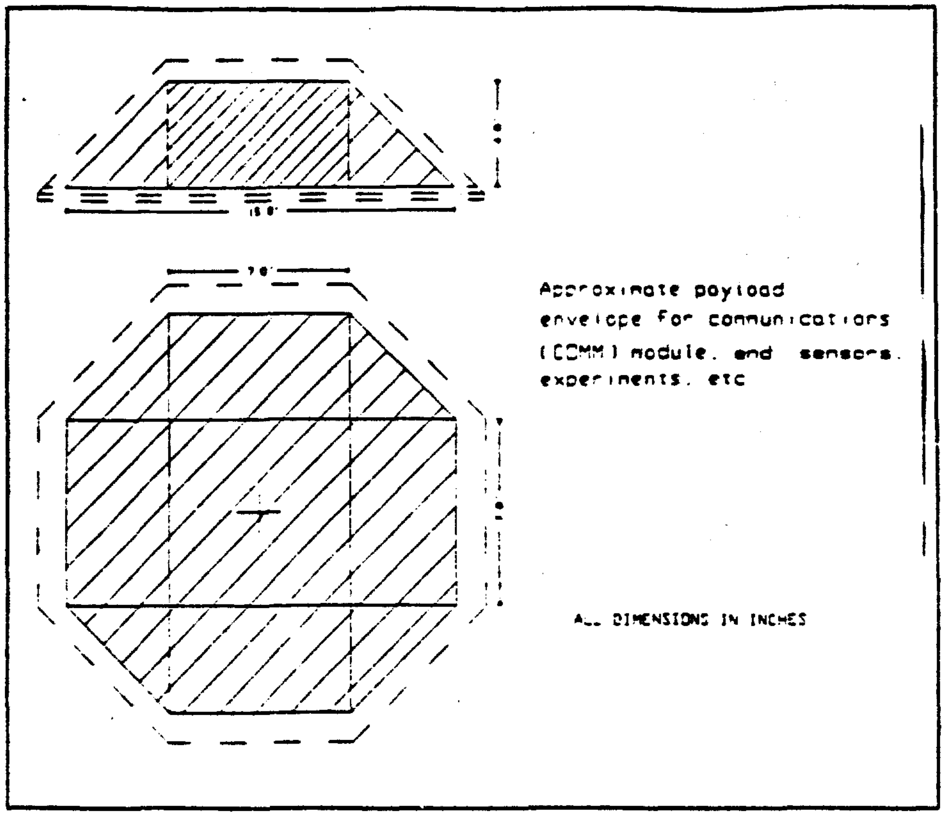
15.0"
7.0"
Approximate payload envelope for communications (COMM) module, and sensors, experiments, etc
ALL DIMENSIONS IN INCHES

Figure 18. PANSAT Communications and Experimental Payload Envelope

spread spectrum communications, in which it might be advantageous to spread the signal over more than 3 MHz. This option is not available, so PANSAT spreads the signal out to 960 kHz.

The attitude and inclination of the satellite's orbit are very important design considerations. These two parameters have a direct effect on establishing the spacecraft's ground footprint. That is the area of the earth from which the satellite is in line-of-sight at a particular time. By increasing the orbital altitude, the ground swath width, or footprint diameter, increases as well. The space shuttle generally deposits satellites in the 300 km to 500 km altitude range. A satellite without a propulsion system, such as

PANSAT, is unable to kick itself into a higher orbit. At zero elevation angle, the ground swath width at 300 km is 3783 km. By increasing the orbital altitude to 500 km, the ground swath width also increases to 4824 km, an increase of 1039km [Ref. 13: p. 6]. The important factor effected by the size of the satellite footprint is the time in view. Since UHF communications can only be conducted while line-of-sight, an increased ground swath width means more operational time.

The shuttle usually launches at an orbital inclination of 28.5°, roughly the latitude of the Cape Kennedy launch site. While an increase in inclination will not vary the size of the satellite's earth footprint, it does change the geographical location of the ground track. An increased inclination spreads out the ground tracks, covering more territory at higher latitudes and spending less time at lower latitudes. The lower inclination ground tracks are all bunched up around the equator. A satellite with an orbital inclination of 28.5° follows a sinusoidal path about the equator, with the amplitudes of the sine curve at 28.5° north and south latitude. Increasing the inclination to NPS's latitude of 36.5°, would increase the peak to peak distance of the orbital sine curve, giving the higher latitudes slightly more coverage and the equatorial regions less coverage. Depending upon the location of the ground station, an inclination increase may or may not be beneficial. The objective is to increase time-in-view and subsequently operational time. At an orbital altitude of 480 km and a 28.5° inclination, a ground station at NPS would average 56 minutes of time-in-view per day (for eight passes). Changing the inclination to 36.5° and retaining the same altitude, the NPS ground station would average 73 minutes time-in-view per day [Ref. 13: p. 10]. That is an increase of 17 minutes per day. If a shuttle is used as the launch vehicle, however, the anticipated orbital parameters will be 480 km altitude and 28.5° inclination. Figures 19 and 20 show PANSAT's anticipated ground track and earth footprint, respectively.

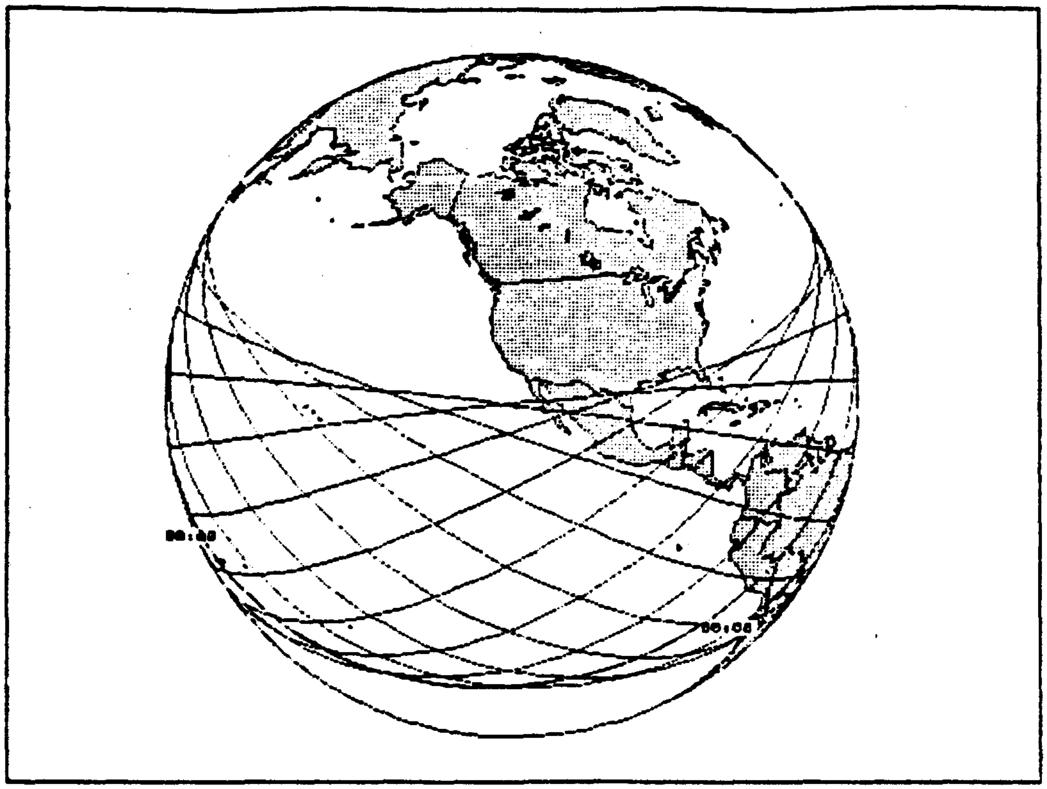

Figure 19. PANSAT Ground Track (480 km, 29°)

The method of attitude control is an important design consideration for a satellites communication system, specifically the antenna design. PANSAT has no attitude control and therefore tumbles randomly. As such, the satellite antenna must be omnidirectional. Because the antenna orientations would not be known, circular polarization is used. The satellite must be designed so that the body of the spacecraft does not block the signal path. No matter how the satellite is oriented, a lobe of its radiation pattern must point earthward. Throughout the orbit, users will experience gains and nulls as the satellite tumbles. During a null period, the gain decreases and the bit

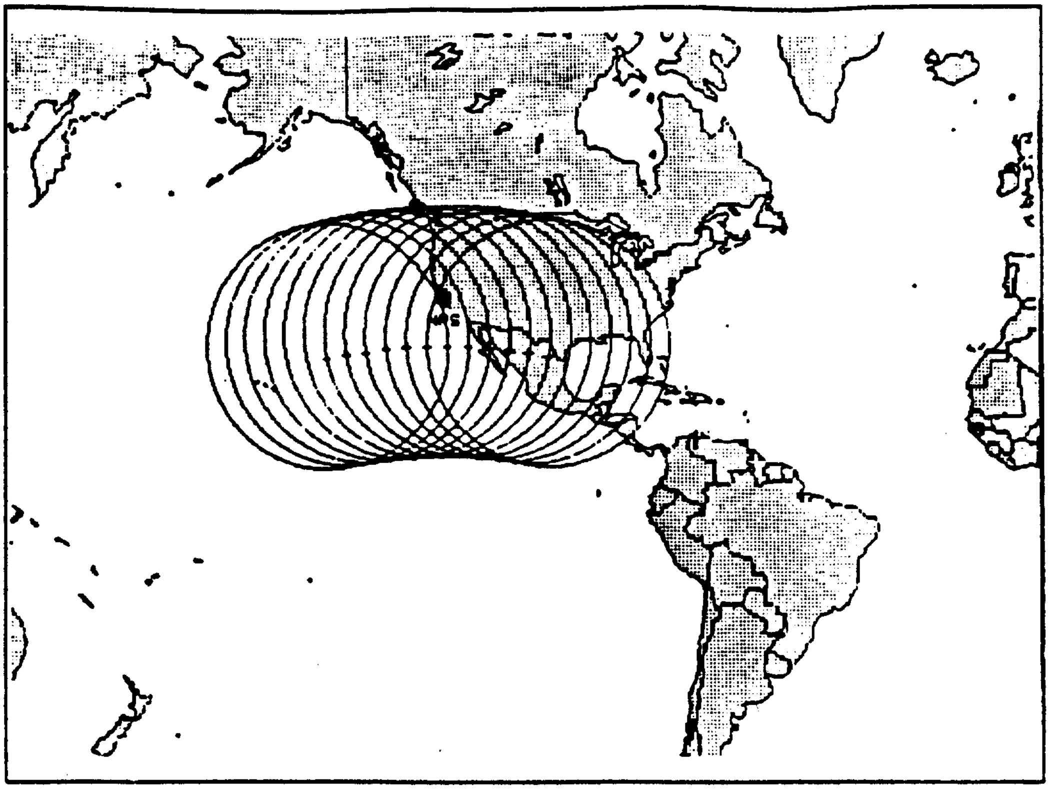

Figure 20. PANSAT Earth Footprint (480 km, 29°)

error rate increases. The assumption made with PANSAT was a maximum null of 10 dB [Ref. 13: pp. 12-13].

The number of users and consequently, the amount of message traffic must also be considered. PANSAT limits the number of users that it services through the use of spread spectrum. The average amateur radio operator does not have either the time, resources, knowledge or resolve to build the associated decoding boards required for spread spectrum communications. Only those highly motivated amateurs interested in working with spread spectrum communications will have the determination to undertake such a project. The limited number of users minimizes message collisions [Ref. 13: p. 14].

The types of ground stations which use the satellite is an important consideration when calculating the link budget. What are the different received signal powers to be expected by PANSAT's receiver? The primary ground station is located at NPS. NPS also plans to build a mobile station [Ref. 13: p. 15]. The exact characteristics for these two stations are known. However, the remainder of the operational stations are private amateur stations scattered around the globe. Exact values for these stations are not known. Average characteristics for amateur stations are included in Appendix E.

One of the first steps taken when starting the satellite communications design is to calculate the link budget. The following table contains PANSAT's link budget for the worst case maximum range scenario [Ref. 13: p. 23].

Table 3. PANSAT LINK BUDGET

PARAMETER	UPLINK	DOWN-LINK
Frequency	437.25 MHz	437.25 MHz
Transmit Power	0 dBW	7 dBW
Antenna Gain	2.1 dB	0 dB
EIRP	2.1 dBW	7 dBW
Slant Range	2025.3 km	2025.3 km
Free Space Loss	151.4 dB	151.4 dB
Antenna Temperature	161.9°K	290°K
L_e	1.0	1.0
F (Preamp)	4 dB	4 dB
G (Preamp)	12	12
F (Down Converter)	7 dB	7 dB
T_v	28.3 dB°K	29.0 dB°K
B	59.8 dB-Hz	59.8 dB-Hz
C/N	4.2 dB	10.5 dB
R_b	1200 bps	1200 bps
E_b/N_o	9.6 dB	9.6 dB
M_s	16.4 dB	16.4 dB

It is not the purpose of this thesis to get into too much detail about the intricacies of spread spectrum communications, however, some features are explained in detail for the purpose of presenting design considerations pertaining to this satellite's communication system. Firstly, an overview of PANSAT's communication system, as designed to this date, is in order. Figure 21 depicts PANSAT's communication system, with an expanded view of the receiver block [Ref. 13: pp. 26-27].

In figure 21, the higher hierarchical level shows the complete communications system. This is a half-duplex system in which the single antenna is time shared by the transmitter and receiver. A mechanical switch completes the appropriate circuit. The

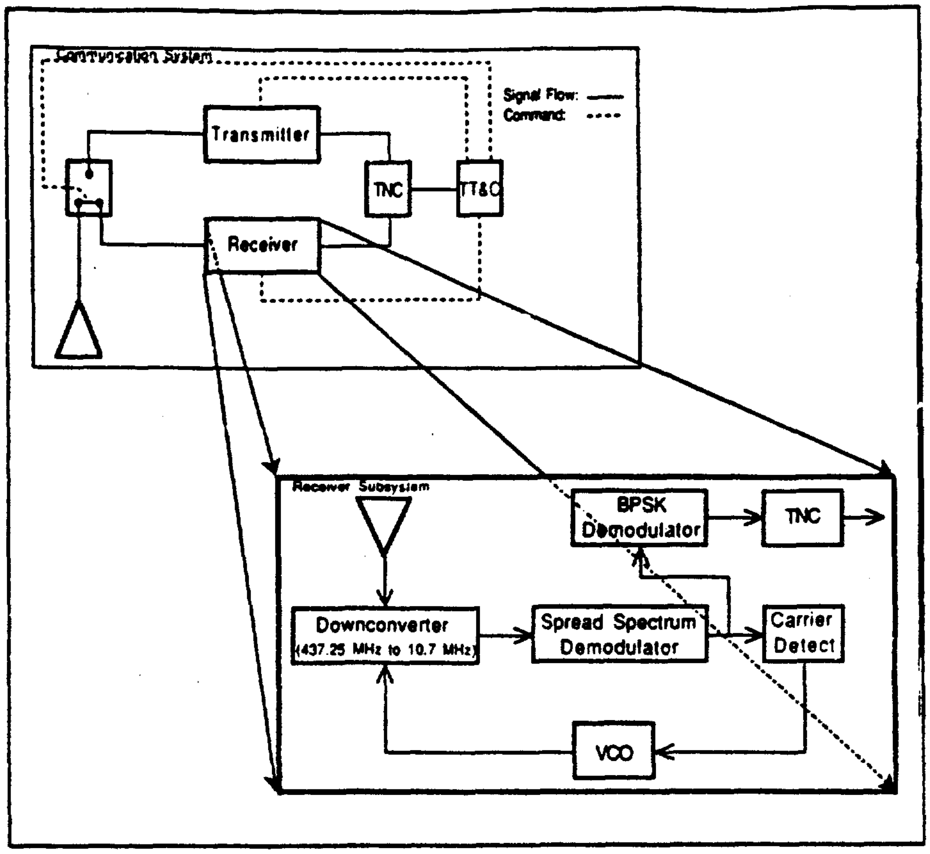

Figure 21. PANSAT's Communication System

Terminal Node Controller (TNC) interfaces the Telemetry, Tracking and Control system (TT&C) with the transmitter and receiver. The TNC, using the AX.25 data protocol, reads the packet address and forwards it to the TT&C. The TT&C controls the satellite's operational functions, such as engaging the receiver or transmitter as appropriate. [Ref. 13: pp.25-26]

The lower hierarchical level in figure 21, depicts the receiver makeup. The Voltage Control Oscillator (VCO) in this diagram is the clock source. The downconverter takes the received 437.25 MHz signal and downconverts it to a 10.7 MHz signal. The downconverter also performs an Automatic Gain Control (AGC) function. The AGC limits the total power in the 960 kHz spread bandwidth, allowing a threshold to be set, which is used in the acquisition circuit of the spread spectrum demodulator. The spread spectrum demodulator takes the 10.7 MHz signal, synchronizes it and despreads the signal. The despread signal is sent to the BPSK demodulator, which extracts the message data from the despread signal. The data is sent to the TNC which reads the message address. [Ref. 13: pp. 27-31]

The main task of the spread spectrum demodulator is to perform the initial synchronization of the incoming signal. Synchronization is the most difficult aspect of spread spectrum communications. Synchronization is comprised of two separate tasks: acquisition and tracking. The acquisition of the signal occurs first. The basic idea is to align the received PN code with an internally generated PN code. Once the two codes are aligned, the tracking circuit takes over. Its job is to maintain the acquisition lock by keeping its own code clock rate as closely matched to the received chip rate as possible. There are several methods of tracking available, such as the 'tau-dither' method or the 'delay-lock' method [Ref. 14: p. 248]. PANSAT uses the latter method. PANSAT utilizes an early-late gate correlator, which takes the PN code and creates two versions of the code, an 'early' version and a 'late' version. The early code is shifted back one half chip, while the late code is shifted forward one half chip. The two signals separately modulate the received signal. The two squaring circuit's outputs are subtracted, producing an error signal for the loop filter. The timing of the code clock is maintained such that the error signal is a minimum, thus keeping the two PN codes in sync. The bottom portion of figure 22 shows the tracking circuit [Ref. 13: pp. 32-33].

The top portion of figure 22, just above the tracking circuit is the acquisition circuit. The acquisition circuit initially aligns the two PN codes. PANSAT uses the simplest correlator technique, called a 'sliding' correlator. With this type of correlator, the re-

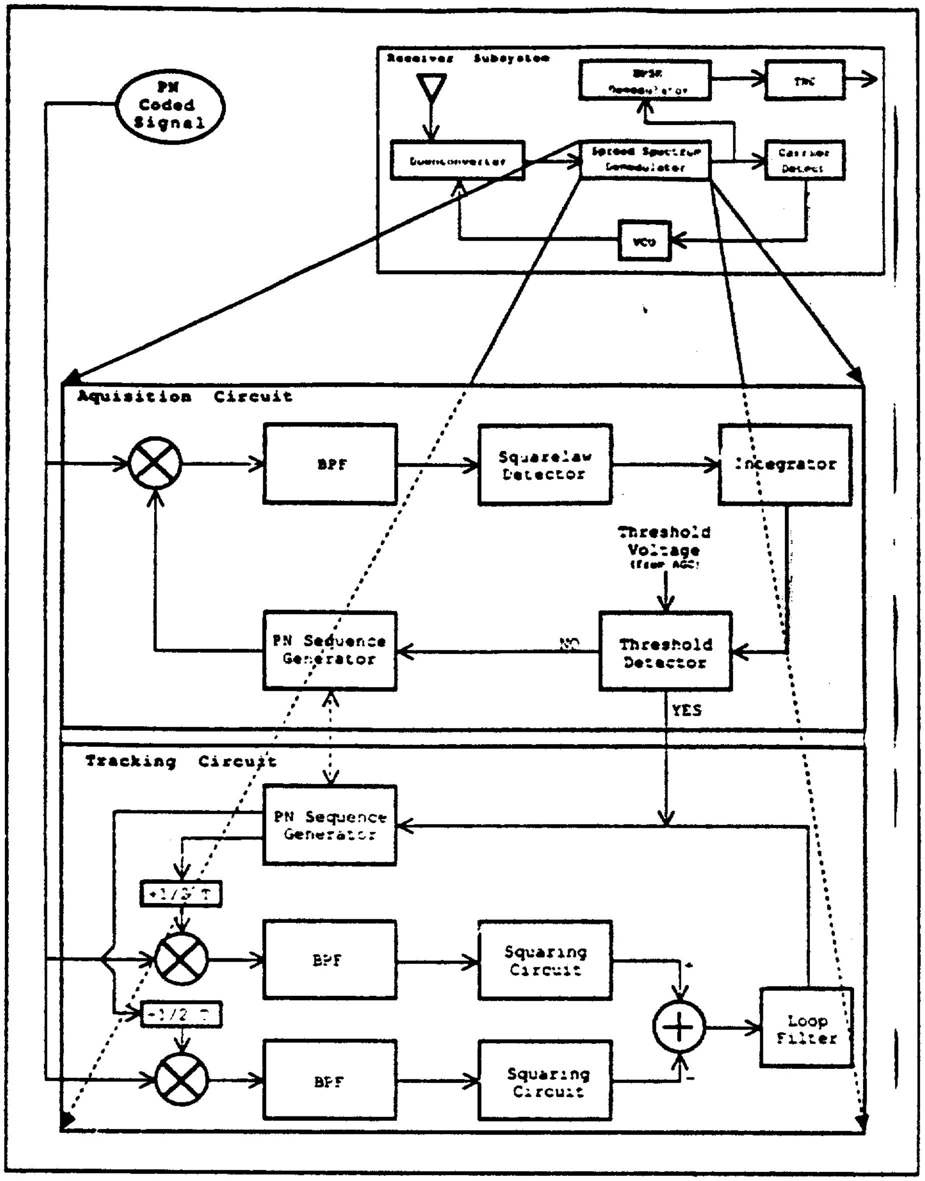

Figure 22. PANSAT Spread Spectrum Configuration

ceiver operates its code clock at a different rate than the transmitter's code clock. The two PN codes then slip in phase with respect to each other. They continue sliding in phase until the threshold detector gets an input voltage from the integrator which is larger than the threshold limit, which was determined by the AGC function in the downconverter. When the limit is surpassed, acquisition has occurred and the tracking circuit takes over. Figure 23 displays a flow diagram for the sliding correlator [Ref. 14: pp. 218-219].

Now that the spread spectrum communications system on PANSAT has been described, it is possible to look at several spread spectrum specific design considerations. Since the average operation window for PANSAT is roughly seven minutes per orbital pass, a major emphasis is made on reducing the acquisition time. If it takes six minutes to acquire the signal, that leaves only one minute for operations. Clearly this is an unacceptable ratio. Also, since PANSAT carries only one antenna, each time the TT&C switches from the transmitter circuit to the receiver circuit, or visa versa, the signal must be reacquired each time. All the more reason to reduce acquisition time. Refer to the top portion of figure 22 through the discussion in this paragraph. A handy formula for calculating acquisition time is $T_{ACQ} = 2NT_{D}$, where N is the PN code length and T_D is the dwell time. The dwell time is the amount of time the integrator is evaluating the signal. The length of the PN code is, therefore, important to the acquisition time. By increasing N, the tracking circuit works better, however, by decreasing N, the acquisition time decreases. It is not practical to shorten the length of the PN code so much that acquisition is excellent, but the tracking circuit cannot maintain lock. A middle ground has to be reached. The integrator dwell time is also important to the acquisition time. By decreasing T_D, T_{ACQ} goes down, but with an increased possibility of determining no sync when in fact sync exists. By increasing dwell time, acquisition time increases. Also, if T_D is increased too much, the probability of a false acquisition increases. So dwell time, like PN code length, is another design consideration.

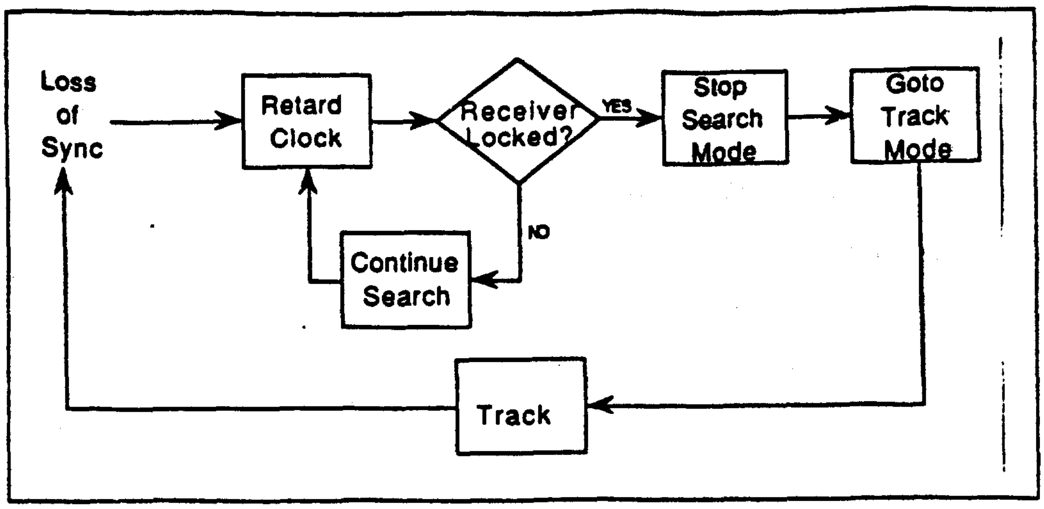

Figure 23. Sliding Correlator Flow Diagram

Dwell time follows the relationship $T_D = \frac{T_r}{2}$, where T_r is the rise time. The rise time is the time it takes the bandpass filter (in figure 22) to go from no pass to maximum pass. Basically, T_r is a measure of the sharpness of the corners of the filter's cutoffs. Rise time is related to filter bandwidth by the relationship, $T_r = \frac{0.35}{BW}$. Hence filter bandwidth also influences dwell time. To reduce rise time and consequently dwell time but ultimately acquisition time, the bandpass filter bandwidth should be large. The limiting factor is that the wider the filter bandwidth, the more noise is introduced into the signal, reducing the signal-to-noise ratio. [Ref. 15] There are many such factors to consider when attempting to increase satellite operational time.

B. EXPERIMENTAL PAYLOAD

PANSAT was designed to be able to support small experiments having minimal power, weight and space requirements. One such experiment is a solar cell parameter measurement experiment. Originally, this experiment was to be an experiment which tests the on-orbit annealing of radiation damaged cells. Due to PANSAT's low orbit of 480 km, and low inclination of 28.5°, it was determined that not enough radiation damage would be incurred on the solar cells to optimize the conduction of the experiment. As a result, the solar cell parameter measurement experiment was substituted in its place. The experiment measures the effects of the space environment on solar cell performance.

Recognizing the requirement to test solar cells while on-orbit, Dr. S. Michael and Lt. R. Callaway, of NPS, developed a novel solar cell test circuit which produces an accurate representation of a solar cell I-V curve. These curves are accurate to within 2 mV from a 12 bit analog-to-digital converter [Ref. 8: p. 10]. The circuit uses the concept that a bipolar junction transistor models an ideal current source. Using the transistor to control the output current of a solar cell makes it possible to measure the short circuit current of the cell. Measuring different currents and corresponding voltages is possible by changing the current using the transistor base as the control [Ref. 16 : p. 3]. An example of a silicon solar cell I-V curve is shown in figure 24 [Ref. 17: p. 31]. Dr. Michael provides the following description of the solar array I-V tester [Ref. 16: p. 3]:

> This circuit in its simplest form has 5 volts placed on the anode of the solar cell which has its cathode tied to the collector of a 2N3405 transistor. The emitter of the transistor is connected to ground through a 10 ohm resistor. The base is stepped through voltages to bias the transistor from cutoff through the active region. By simultaneously measuring the voltage across the solar cell and the voltage across the emitter resistor, the corresponding values of the cell VI characteristics can be recorded. This is true since using a high beta 2N3405 transistor would allow us to ignore the base current. Thus we can measure values of the current in the emitter resistor as the collector current or the solar cell current.

A schematic of the simplest form of this circuit is depicted in figure 25 [Ref. 17: p. 13]. In this figure, the solar cell being tested provides a load to the transistor. No current is allowed to flow to the base of the transistor, so $I_b = 0$. The collector and emitter currents, I_c and I_e, are equivalent. The solar cell circuit voltage is the difference between the power source voltage (5 volts in this case) and the collector voltage, so $V_s = V_c - V_{ce}$. The circuit current is equal to the product of the emitter voltage and the

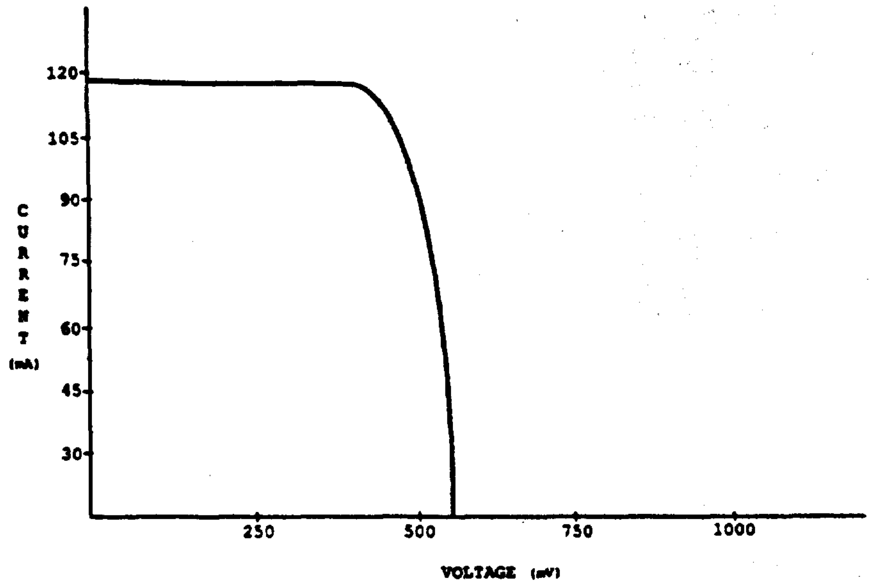

Figure 24. Solar Cell I-V Curve

emitter resistance (10 Ω in this case), so $I_s = I_e = \frac{V_e}{R_e}$ Because there is not much current drain, I_e and therefore I_s approximate zero. This provides one endpoint for the solar cell's I-V curve. When V_b is increased, V_e decreases, thereby increasing current drain until V_s goes to zero and the solar cell current, I_{sc}, is reached. Data points for the entire I-V curve can be obtained by stepping input voltages to the transistor base and measuring V_s and V_e [Ref. 17: pp. 12-13].

In the solar cell parameter measurement experiment, the I-V testing circuit is coupled with a microprocessor based controller system, designed by Lt. R.S. Oxborrow. The system has the capacity to collect, validate and store data pertaining to solar cell

V_{ps} = Power Source Voltage
V_s = Solar Cell Circuit Voltage
V_b = Transistor Base Voltage
V_e = Transistor Emitter Voltage
V_c = Transistor Collector Voltage
I_e = Emitter current
R_e = Emitter Resistance
I_s = Solar Cell Circuit Current

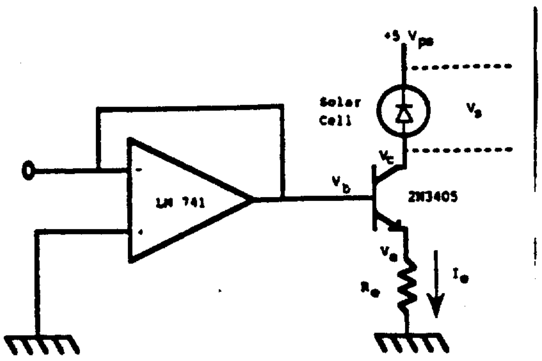

Figure 25. Novel Solar Cell Biasing Circuit

performance I-V curves. The complete system is composed of an NSC 800 microprocessor, digital-to-analog and analog-to-digital converters, analog multiplexers/demultiplexers, biasing transistors and op-amps. The designed experiment provides a compact, simple, low powered and accurate method to measure and store solar cell operational parameters, via their I-V performance curves [Ref. 17: p. iii]. To illustrate the compactness, the size of the computer controller, when not encased is 3 by 4.5 by 1.5 inches. The test array consists of eight cells [Ref. 16 : p. 4].

The solar cell parameter measuring experiment is a subset of the previously planned on-orbit annealing experiment. The I-V curves produced by the measurement experiment would be used to determine the maximum power point. The maximum power point, in turn, is used in the algorithm for energizing anneal circuitry in the annealing experiment. PANSAT provides the platform which will allow the measuring experiment subset to be tested and perfected so that the annealing experiment, carried on a future satellite, will proceed smoothly.

The possibility exists that PANSAT may also carry additional experiments, provided they conform to size, weight and power restrictions. One such experiment being considered is an experiment which tests the new technology of ferroelectric memory. Ferroelectric memory is suited for space applications, due to its inherent radiation tolerance, non-volatility and high memory density. Detractors from this technology are endurance and retention. [Ref. 8: p. 12]

V. CLASSROOM USES FOR A SATELLITE

Besides providing the bus which contains the experimental payload, and giving the amateur radio community an opportunity to utilize spread spectrum communications, PANSAT can be used in the classroom to illustrate many aspects of space science. One of PANSAT's functions is to serve as an on-orbit laboratory for students in the Space Systems Academic Group (SSAG) at NPS. This chapter presents several space systems areas in which detailed experiments could be developed to provide hands-on experience to the student and reinforce lecture material.

Many experiments could be devised in the area of satellite tracking. Students could determine the classical orbital parameters of the satellite from actual observation. Tracking experiments can be used to illustrate basic satellite orbit terminology, to determine PANSAT's period, to predict the time at which communication is possible, and to determine the satellite's attitude. Since PANSAT is in a circular orbit, the only equipment required to determine orbital parameters is a ground receiver, an antenna and a clock. The tracking experiment would proceed in the following manner. First calculate the time of closest approach for the first orbit by averaging the two times of initial contact and lost signal. The same is then done for the next orbit. The elapsed time between the two times of closest approach is the first estimate of the period. Using Kepler's Law, the satellite altitude can be calculated from the equation $P^2 = (\frac{4\pi^2}{GM})r^3$, by solving for the radius r. Using data from additional orbits increases the accuracy of the estimated parameters. Variations of this experiment would allow the student to obtain additional information. For example, the use of a directive antenna would allow the student to estimate the orbital inclination. PANSAT as an on-orbit laboratory would be useful to instructors teaching orbital mechanics by proving the validity of Kepler's

Laws. Additional experiments are possible to determine the satellite's elevation and slant range as a function of time, its position in the orbital plane as a function of time, and to produce the satellite's ground track. [Ref. 18 : pp. 6.2-6.5]

Another type of experiment which could be performed using PANSAT is one in which orbital parameters are calculated using the doppler effect. The doppler effect is the change in the frequency observed from a stationary observer in a fixed reference frame as an emitter moves toward and then past the observer. In this experiment, the ground station is the observer and the satellite is the emitter traveling at velocity V. The satellite needs to emit a constant beacon signal. Best results occur when the satellite is close to overhead. From the beginning of the satellite signal until the signal is lost in a pass, a table should be kept showing time and observed frequency. Using the data from this table, a frequency-versus-time, Doppler graph, can be constructed. Figure 26 is an example of a doppler graph [Ref. 18: p. 6.18]. The time at which $\frac{\delta f}{\delta t}$ is a maximum (the inflection point on the doppler graph) is the time of closest approach (TCA). To estimate the period, repeat the above procedure on the next pass, producing another Doppler graph. Determine the TCA for this pass. The orbital period is the time difference between the two TCAs. For a circular orbit, satellite velocity is given, $V = (\frac{2\pi GM}{\mathbb{P}})^{1/3}$, where $\mathbb{P}$ is the period, G is the gravitational constant, and M is the mass of the earth. The slant range at TCA can be obtained using the formula, $\rho_o = -\frac{f_c V^2}{c(\delta f / \delta t)_{max}}$, in which ρ_o is the slant range, F_o is the transmitted frequency and c is the velocity of light in a vacuum. [Ref. 18: pp. 6.12-6.17]

Students can gain valuable space experience using PANSAT by transmitting command messages to and evaluating received telemetry data from the satellite. Telemetry data shows the status of all the systems aboard the satellite. This could include information such as the voltage produced by each individual solar panel or internal environmental temperature. NPS students could devise several experiments utilizing the

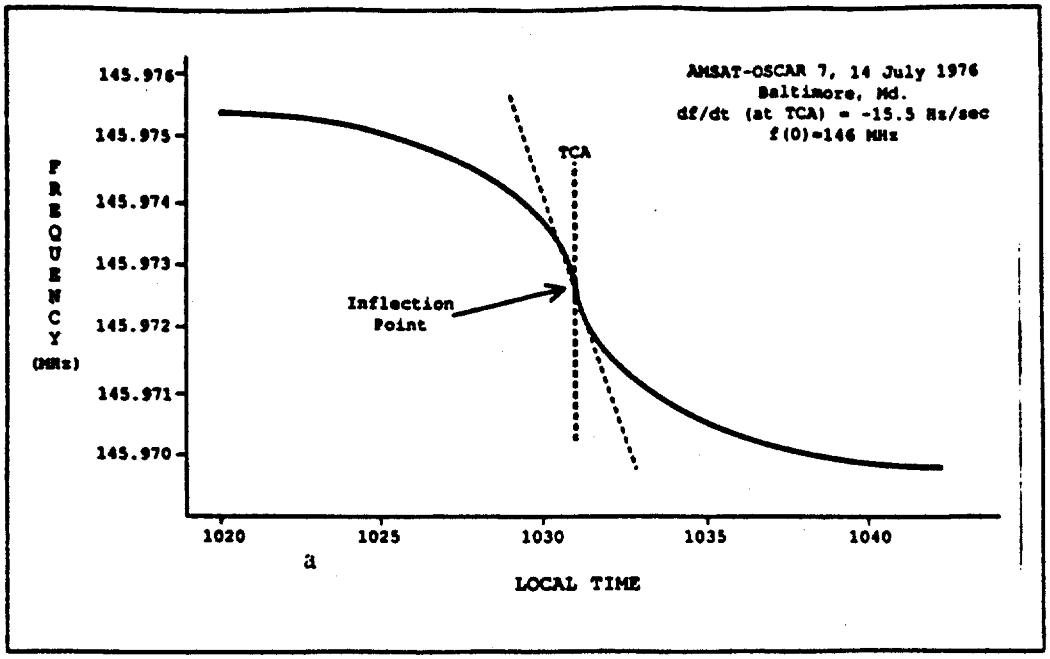

Figure 26. Doppler Graph

telemetry data. An experiment could be developed to determine the orientation of the spacecraft using voltage readings from individual solar cells. The equilibrium temperature of the satellite could be determined and used to demonstrate the heat balance equations. Energy balance equations can be used to determine the available power to operate the satellite's equipment (ie. to explain the power budget). Experiments can be made to measure the solar constant or the albedo of the earth from sunlight reflected off the earth's surface, which strikes the earthward solar panels. [Ref. 18: pp. 6.27-6.44]

Another concept which could be explained by a satellite experiment is Faraday Rotation. Faraday Rotation is the rotation of the plane of a linearly polarized wave about the axis of propagation. The phenomena is caused by the earth's magnetic field. Faraday Rotation results in the degradation of signal strength. By computing the drop in signal strength from other factors such as satellite orientation, receiving antenna pattern, ionospheric absorption and radial distance from the receiver, and subtracting these from the total signal loss, the loss due to Faraday Rotation is left. [Ref. 18: pp. 6.46-6.47]

NPS students may also devise a way to use PANSAT to radiolocate a signal on the earth's surface. A practical application of radiolocation is to find downed aviators. Most aircraft automatically activate an Emergency Locator Transmitter (ELT) when an emergency is declared. Using the doppler effect previously discussed in this chapter, PANSAT could detect an ELT signal and relay the signal to a ground station. The ground station could create a doppler graph as in figure 26. The TCA of the satellite to the ELT occurs at the inflection point of the curve. PANSAT's nadir point at this time can be plotted. If the same thing is done for a couple of orbits, the ELT's location can be triangulated. This technique has been used in the past on NASA's Search And Rescue SATellite (SARSAT) of the 1970's. [Ref. 19: p. 63]

The ideas presented in this chapter have only hinted at the multitude of experiments which are possible using a satellite such as PANSAT. Experiments can be done to reenforce student understanding of lecture material covering the space sciences. Many academic departments at NPS could benefit from this type of laboratory experience. The only limiting factor is the students' imagination.

VI. INTERNATIONAL SPECTRUM MANAGEMENT

With this chapter, the study leaves the satellite design consideration topic and addresses the satellite licensing problem. When a satellite is licensed, the desired result is that an operating frequency is requested and approved. Before explaining the various licensing routes possible for PANSAT, it would be helpful to understand the structure and roles of the frequency spectrum regulating agencies. This chapter describes the most senior of the regulating agencies, the International Telecommunications Union (ITU). The two national level agencies, the Federal Communications Commission (FCC) and the National Telecommunications Information Administration (NTIA), are discussed in the following chapter.

A. THE INTERNATIONAL TELECOMMUNICATIONS UNION

The worldwide organization which manages frequency allocations is the International Telecommunications Union (ITU). Within the geographical confines of each country, a national regulatory organization is responsible for the licensing of radio stations and the assignment of frequencies. In the United States, the FCC and the NTIA jointly maintain regulatory control. The FCC and NTIA are required to notify the ITU of any frequency assignments or license approvals. If the ITU does not foresee any interference or international conflict, it approves the action and officially records it.

The main role of the ITU is to settle conflicts between member nations pertaining to the field of telecommunications. The ITU, originally known as the International Telegraph Union, was founded in Paris, France in 1865. In 1932, the name was changed to its present form when additional duties, relating to telephony and radiocommunications, were incorporated into its charter. In 1947, the United Nations made the ITU a UN specialized agency for international telecommunication matters.

Presently, 162 nations, including the United States, are members. [Ref. 20: p. 62] Today, the ITU is located in Geneva, Switzerland.[1]

The central document of the ITU is the International Telecommunications Convention. The Convention has international treaty power. In fact, the Convention is a treaty between the member nations which specifies the ITU's basic structure, objectives, budget and operating procedures. The Convention may only be altered by the Plenipotentiary Conference, which meets once every seven years. Subservient to the Convention are the Radio Regulations, Telegraph Regulations and Telephone Regulations. These regulations may be revised by Administrative conferences. [Ref. 21 : p. 126]

The overall objectives of the ITU are threefold. First, to promote international cooperation among all members of the ITU, to improve the use of telecommunications of all types, and to provide technical assistance to developing countries. The second ITU objective is to promote the development of more efficiently operating technical facilities to improve communications service and to make them available to the general public. The final objective is to achieve the first two objectives in such a manner as to cause the least friction between the members. [Ref. 22: Art. 4] In order to accomplish the three objectives, several specific tasks are performed by the Union. To better understand the tasks, the structural breakdown of the Union is presented, to be followed by tasks performed by each substructure.

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[1] For those interested in contacting the ITU, the mailing address and phone number are:

ITU
International Telecommunications Union
Place des Nations, CH 1211
Geneva 20, Switzerland
Telephone: (022) 34 60 21
Telex: 23000

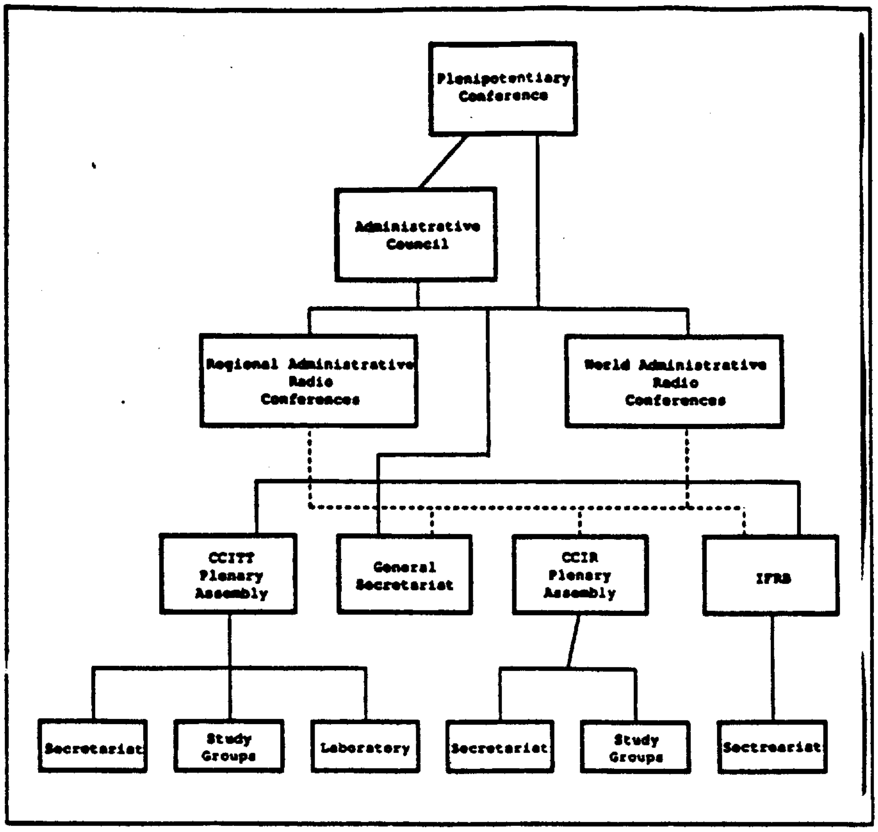

Figure 27. ITU Organization

Structurally, the ITU is comprised of two categories of organs: the international conferences and the permanent organs. There are three types of ad-hoc structures (international conferences). They are the Plenipotentiary Conference, the Administrative Council, and the Administrative Conferences. Hierarchically, the three ad-hoc structures are senior to the permanent organs. Figure 27 depicts the ITU's overall structural relationships. There are four permanent organs in the Union. They are the General Secretariat, the International Frequency Registration Board (IFRB), the International Telegraph and Telephone Consultative Committee (CCITT) and the International Radio Consultative Committee (CCIR). [Ref. 23: pp. 3-5]

The Plenipotentiary Conference is the most powerful organ in the Union. It is composed of one representative from each member country. The conference meets every seven or eight years. The Plenipotentiary, determines when it will meet, based upon recommendations by the General Secretariat. In the Plenipotentiary Conference, as in all three types of international conferences, the conferences are organizations of equals. No ITU staff or senior conference delegate has authority over other delegates [Ref. 23: p. 3]. The Plenipotentiary Conference performs several tasks, the most important of which are listed here [Ref. 22: Art. 6]:

1. Determine general policies of the Union.
2. Revise the ITU Convention if required.
3. Elect members of the Administrative Council.
4. Elect members of the IFRB.
5. Elect the Secretary-General (Head of the General Secretariat).
6. Elect the directors of the CCIR and the CCITT.
7. Provide a budget setting fiscal limits until the next Plenipotentiary Conference.
8. Make decisions dealing with staffing, salaries and pensions.
9. Conclude or revise agreements with other international organizations.
10. Answer other telecommunications related questions as required.

While the Plenipotentiary Conference is the supreme organ of the Union, the Administrative Council actually governs the Union. The Administrative Council is composed of 41 members, all of which are elected by the Plenipotentiary. The Council meets annually for a three week period. During the interval between Plenipotentiary Conferences, the Administrative Council acts on behalf of the Plenipotentiary, within the delegated limits of power. The four major tasks of the Council are [Ref. 22: Art.8]:

1. Perform duties as assigned by the Plenipotentiary, to include the implementation of the rules and regulations contained in the ITU Convention and the Administrative Regulations.
2. Each year create a technical assistance policy in accordance with ITU objectives.
3. Coordinate the work of the ITU and control the fiscal spending of its permanent organs.
4. Promote international cooperation by giving technical assistance to developing countries.

The final ad-hoc structure in the ITU is the Administrative Conference. Structural organizations vary for this conference, depending upon the mandate of the particular conference. Administrative Conferences are convened whenever there is a subject, or conflict, to discuss of a pertinent matter [Ref. 23: p. 5]. Administrative Conferences are normally held to discuss very specific telecommunications matters. Subjects not included in the agenda may not be discussed at the conference. All decisions reached must also be in accord with the ITU Convention. The Administrative Conference does have the power to perform such tasks as making revisions to the Administrative Regulations or the Radio Regulations. [Ref. 22: Art. 7]

There are two types of Administrative Conferences, the World Administrative Radio Conference (WARC) and the Regional Administrative Radio Conference (RARC). WARCs discuss matters on a worldwide scale. Their agendas can have either a broad or narrow scope, depending upon the need. Since World War II, twenty limited WARCs and six broad subject matter WARCs have been held. Of these 26 WARCs, five of them have been called to deal with matters directly related to space communications. They were the 1963 and 1971 Conferences on Space Communications, the 1977 Conference on Broadcast Satellites, and the 1985 and 1988 Conferences on Geostationary Orbits. [Ref. 24: p. 35]

RARCs cover subject matter of a more regional nature. The ITU has separated the earth into three regions. Figure 28 shows the area covered by each region. Region I is comprised of Europe and Africa. Region II contains North and South America. Region III is made up of Asia and the western Pacific. RARCs are called based upon the different needs of each region, which do not affect the other two regions. The member nations of each region meet and make compromises and frequency allocations among themselves. Fourteen RARCs have been held since World War II. An example of a RARC issue occurred in 1983, when the United States called a RARC for Region II to discuss the distribution of slots in the geosynchronous orbit allotted to Region II. [Ref. 24: pp. 35-36]

The first of the four permanent organs in the ITU is the General Secretariat. The head of the General Secretariat is the Secretary-General, who is appointed by the Plenipotentiary Conference. He reports to the Administrative Council each year on the state of the four permanent organs of the Union. The Secretary-General is also the legal representative of the Union. The six functional departments of the General Secretariat include finance, personnel/social protection, computer, conferences and common services, external relations and technical cooperation. As the departments indicate, the

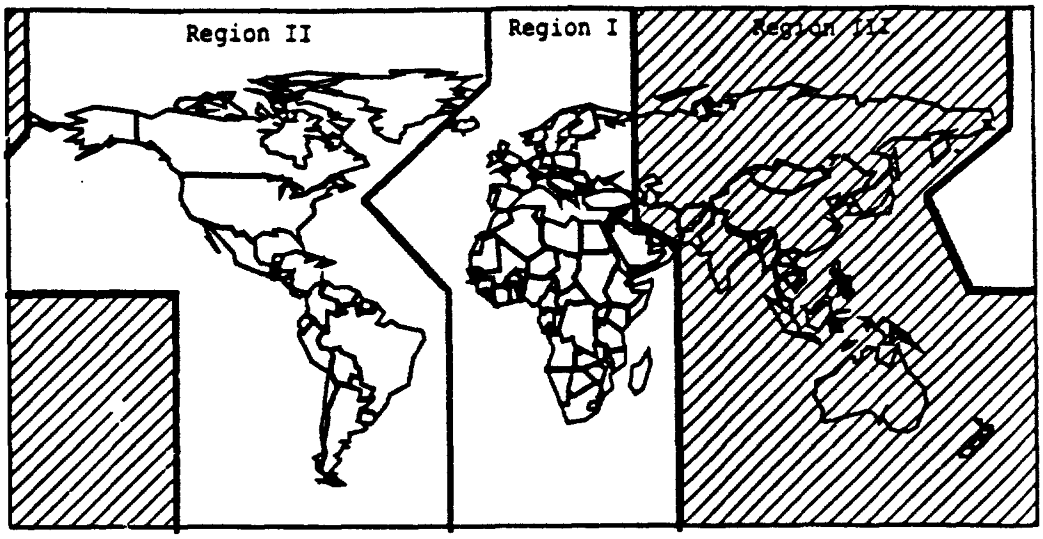

Figure 28. ITU Geographical Regions

General Secretariat handles the financial and administrative aspects of the Union [Ref. 22: Art. 8]. In the arena of space communications, the General Secretariat is tasked with overseeing the publication and exchange of information regarding satellite communications. The General Secretariat also runs the technical cooperation programs to promote the development of satellite communications in developing countries [Ref. 25: pp. 36-37]. These tasks are specifically accomplished by publishing such material as the *Telecommunication Journal* and by providing professional instructors and advisors to developing nations.

The International Frequency Registration Board is the second of the four permanent organs. The IFRB is composed of five members who are elected by the Plenipotentiary Conference. The Administrative Council can replace IFRB members in years in which the Plenipotentiary does not meet. The major function of the IFRB is to receive notifications from member countries, informing the Board of the country's assignment of a frequency to an individual local station. The IFRB then determines whether or not that assigned frequency may create harmful interference in another country. If not, then the frequency is entered into the Master International Frequency Register, which the IFRB is tasked to maintain. If it is deemed that interference will occur, the IFRB notes the problem and serves as an international negotiator between the countries in conflict, for the purpose of attaining a compromise solution. As an example, in 1975, the IFRB negotiated such a compromise solution between INTELSAT, the USSR, India and Indonesia [Ref. 24: p. 34]. Additional tasks performed by the IFRB include [Ref. 22: Art. 10]:

1. Recording positions in geostationary orbit assigned to individual countries.
2. Furnishing advice on frequency assignment and geostationary satellite slot assignment.
3. Maintain the records of each assignment.
4. Prepare reports for and participate in WARCs and RARCs.
5. Advise members on allocation of frequencies, geostationary slots and interference issues.
6. Perform any additional duties concerning the assignment and utilization of radio channels and orbital slots.

The Radio Consultative Committee is the third of the ITU's permanent organs. Its director is elected by the Plenipotentiary Conference. The CCIR carries a permanent staff called the Specialized Secretariat. Every four years, the CCIR calls a Plenary Assembly to construct a list of technical and operational questions which need to be studied. These questions are divided up among several study groups. The study groups are composed of ITU member country representatives, international organizations, CCIR specialized secretariat staff, recognized private agencies plus scientific and industrial organizations. The study groups draw up recommendations which, after approval by the Plenary Assembly, are used in WARCs and RARCs. [Ref. 25: p. 37]

Several of the study groups deal directly with space communications. Some examples of space related topics discussed in the last Plenary Assembly are fixed satellite service, space research and radioastronomy, propagation in non-ionized media, mobile and satellite broadcasting services, and standard time and frequency [Ref. 23: p. 5]. The Convention recaps the duties of the CCIR as follows [Ref. 22: Art. 11]:

> ...to study technical and operating questions relating specifically to radiocommunications without limit of frequency range and to issue recommendations on them.

The CCIR's sister Committee is the International Telegraph and Telephone Consultative Committee. It is the final permanent organ of the Union. The structure of the CCITT is much the same as the CCIR. The director is elected by the Plenipotentiary Conference and it also carries a permanent staff called the Specialized

Secretariat, located in Geneva. The CCITT does its work in study groups similar to the CCIR. A sampling of topics for the study groups include transmission systems and equipment, digital technology, telematics, telegraph networks, data communication, signaling and switching and regional tariff groups [Ref. 23 : pp. 31-35]. The Convention describes the duties of the CCITT as follows [Ref. 22: Art. 11]:

> ...to study and issue recommendations on technical, operating and tariff questions relating to telecommunication services, other than technical or operating questions relating specifically to radiocommunications.

The CCITT studies the use of telecommunications and the types of signalling associated with different types of information. The CCITT is involved in space communications in the area of satellite circuit integration into different networks. Some space related study group topics have included digital speech interpolation, the use of satellite circuits for data transmission, and the effects of long propagation times on signalling systems. [Ref. 25: p. 36]

In many instances, the two Consultative Committees work together on related subjects and jointly publish journals on subjects of interest. The reports produced by the two Committees are the technical basis on which the WARCs and RARCs act to effect changes in the ITU Radio Regulations.

This section has briefly described the structure and function of the ITU. The ITU is the grandfather organization which the FCC and NTIA of the United States must notify when assigning frequencies to new stations, revising frequency assignments to old stations, or assigning geostationary orbit positions. The notifications and requests for license for PANSAT, which are sent to the FCC for an amateur satellite, eventually must be approved by the ITU. The IFRB is the specific entity within the ITU which would be involved with PANSAT's approval for license. Since its birth in 1865, and since it first became involved with satellite communications in 1959, after the 1957 launch of Sputnik, the ITU has been highly successful in resolving communications conflicts.

VII. FEDERAL FREQUENCY REGULATING AGENCIES

The ITU, acting upon the recommendations of its WARCs and RARCs, has assigned an allotment of radio channels to member nations, which the individual countries are responsible to regulate within their borders. In the United States, frequency regulation is performed by two independent agencies, the Federal Communications Commission (FCC) and the National Telecommunications and Information Administration (NTIA). Both agencies were created as a result of sections 303 to 305 of the Communications Act of 1934, which addresses the regulation of wire and radio commerce within and across U.S. borders. The FCC is responsible to regulate telecommunications operated by the private sector, while the NTIA assigns frequencies and regulates systems operated by the federal government [Ref. 26: p. 3.5]. Prior to 1978, the NTIA was known as the Office of Telecommunications Policy (OTP) [Ref. 27 : p. 401].

Looking at the National Table of Frequency Allocations [Ref. 28], it shows that the NTIA and the FCC each individually control about 30% of the U.S.'s allotted frequencies. The remaining 40% are controlled jointly by the two agencies. As a result of the shared frequencies, the NTIA and FCC must coordinate many of their activities. For example, FCC representatives serve on the NTIA's Interdepartment Radio Advisory Committee (IRAC). The IRAC is described later in this chapter. Conversely, the NTIA contributes to the FCC rulemaking process [Ref. 29 : p. 76]. Because the frequency spectrum is a limited resource and there are increasing requirements for spectrum usage, both the FCC and NTIA must work together to create a long range plan that will meet the requirements anticipated in the future. The remainder of this chapter describes the two national agencies.

A. FEDERAL COMMUNICATIONS COMMISSION

As specified by the Communications Act of 1934, the FCC was created to regulate telecommunications "in the public interest." More specifically, this means the FCC is responsible for spectrum management in the private sector, state and local governments included [Ref. 30 : Sect. 303].[2] The general duties of the Commission have been expanded as technology produces new methods of communications. The Communications Satellite Act of 1962 incorporated satellite communication into the FCC's realm of responsibility [Ref. 31: p. 196]. General tasks to be performed by the FCC include [Ref. 29: p. 3]:

1. To promote the development and operation of broadcast services.
2. To provide efficient worldwide telephone and telegraph services at reasonable rates.
3. To promote the safety of life through the use of radio assets.
4. To use radio and television to strengthen national defense.
5. To coordinate and consult with other appropriate agencies concerning communications.
6. To regulate all broadcast services, through licensing.
7. To review the performance of licensed stations to assure proper operating procedures and that the station is in the public interest.
8. To approve station ownership changes and station technical alterations.
9. To process applications for construction of stations and changes in service.

The FCC is headed by five Commissioners, who are appointed by the President, with the consent of Congress. The President chooses one of the five members to be the chairman. The chairman presides over FCC meetings and represents the Commission in interagency matters. Commissioners serve overlapping five year terms of office. No more than three Commissioners may be from the same political party. All FCC matters are resolved by a majority vote of the Commissioners. Congressional control of the

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[2] For those interested in contacting the FCC's national office, the address and phone number are:

Federal Communications Commission (National Office)
1919 M Street Northwest
Washington, D.C. 20554
phone: (202) 653-8144

FCC is exercised through subcommittees of the U.S. Senate and the House of Representatives [Ref. 24: p. 149]. The Commissioners supervise all activities within the FCC. Matters are discussed at regular open and closed agenda meetings and special meetings.

Assisting the Commissioners perform the previously listed tasks are numerous staff members, who are organized into four bureaus and seven offices. Figure 29 depicts the FCC's structure. The four operating bureaus are the Mass Media, Private Radio, Field Operations and Common Carrier Bureaus. The seven offices are the Offices of Plans and Policy, Administrative Law Judges, Opinions and Review, Public Affairs, General Council, Science and Technology, and the Office of the Executive Director. Descriptions of each office and bureau follow.[3]

In 1982, the FCC merged what was then called the Broadcast Bureau and the Cable Television Bureau to form the present Mass Media Bureau. This bureau is responsible for regulating AM and FM radio, television broadcast stations and cable television networks. In the space arena, the Mass Media Bureau is tasked with the regulation of Direct Broadcast Satellites (DBS) in coordination with the Common Carrier Bureau. [Ref. 24 : p. 150]

The Common Carrier Bureau is charged with the regulation of radio and wire communication services such as radio, telegraph, facsimile and satellite services. This bureau licenses the above services and establishes the rates in coordination with state authorities. The Common Carrier Bureau is very involved with satellite communications, as it licenses satellites, taxes them and establishes operational restrictions. [Ref. 24: p. 150]

The Private Radio Bureau establishes regulatory control over all other types of radio stations (excepting experimental stations) to include amateur (PANSAT operates here),

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[3] For those interested in contacting the FCC's regional office, the address and phone number are:

Federal Communications Commission (Regional Office)
211 Main Street
Room 537
San Francisco, Ca. 94105
phone: (415) 744-2722

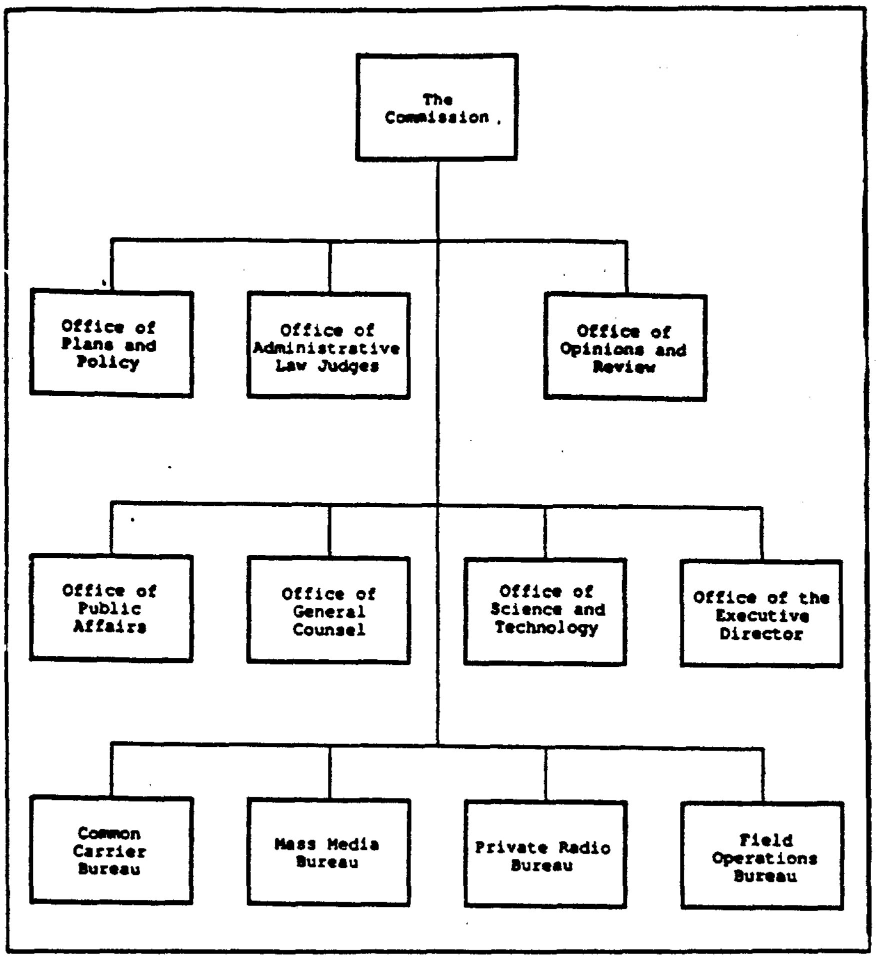
The Commission
Office of Plans and Policy
Office of Administrative Law Judges
Office of Opinions and Review
Office of Public Affairs
Office of General Counsel
Office of Science and Technology
Office of the Executive Director
Common Carrier Bureau
Mass Media Bureau
Private Radio Bureau
Field Operations Bureau

Figure 29. **FCC Organizational Structure**

aviation, CB, public safety (police), marine and industrial stations [Ref. 29: p. 4]. This bureau would license and regulate PANSAT, as it operates in the amateur band as an amateur station. Satellites are looked at in the same manner as a station.

The last bureau, the Field Operations Bureau, conducts engineering work for the Commission. Its responsibilities include inspecting stations, monitoring radio transmissions, detecting radio regulation violations, investigating complaints of interference and handing out violation notices. This bureau has field offices across the country.[4] The Field Operations Bureau also processes radio operator license applications and examinations. [Ref. 29: p. 5]

The functions of the seven offices are well reflected by their titles. The Office of Plans and Policies develop long range plans and policy recommendations encompassing the entire spectrum of the FCC. The Office of Administrative Law Judges preside over FCC hearings and make the Initial Decisions, which are reviewed and approved by the Commissioners. The Office of Opinions and Review assists the Commissioners review the Initial Decisions and make recommendations to be used in the Final Decisions. The Office of Public Affairs is responsible to inform the public of FCC decisions, to promote public participation in FCC decision making, and to advance the cause of equal opportunity in the communications field. The Office of the General Counsel is the legal representative of the Commission. Its tasks include representing the FCC in court and advising the Commissioners on legal matters involving FCC policy. The Office of Science and Technology regulates experimental stations, coordinates standards with the FCC and coordinates international station licenses. If PANSAT could be licensed as an experimental satellite, the license request would go through this office. Finally there is the Office of the Executive Director. His duties are administrative in nature. They include internal administration, health and safety, budget planning and personnel management. [Ref. 29: pp. 3-6]

The FCC publishes a number of periodicals to inform the public of FCC actions. The Office of Public Affairs publishes a daily FCC news release which announces recent

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[4] The address and phone number for the FCC local office is:

Federal Communications Commission (Local Office)
Field Operations Bureau
424 Customhouse, 555 Battery Street
San Francisco, Ca. 94111
phone: (415) 705-1101

FCC actions and propositions. It can be obtained from the FCC Press Office (phone: (202) 254-7674). The FCC also publishes a weekly version of *FCC Reports* and uses the *Federal Register* to publish decisions, orders and policy statements. These publications are available from the Superintendent of Documents, Government Printing Office, Washington, D.C. The rules and regulations of the FCC are located in title 47 of the *Code of Federal Regulations*. Copies of this are also available through the Government Printing Office. [Ref. 26: p. 3.5]

The remainder of the chapter examines the structure and function of the U.S.'s other frequency regulating agency, the NTIA.

B. NATIONAL TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION

The NTIA falls under the Executive Branch of the U.S. government. The President is ultimately responsible for the frequency management of all radio stations belonging to and operated by the government [Ref. 30: Sect. 305]. The President delegates this authority to the Department of Commerce. The head of the NTIA is the Assistant Secretary of Commerce for Communications and Information. Besides regulating governmental use of the spectrum, the NTIA also assigns frequencies for industrial government contracts. [Ref. 26: p. 3.6][5]

The responsibilities of the NTIA can be broken down into three objectives, all relating to spectrum management. The objectives are [Ref. 32: p. 659]:

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[5] For those interested in contacting the NTIA, the address and phone number are:

U.S. Department of Commerce
National Telecommunications and Information Administration
14th and Constitution NW
RM 4099 (for Frequency Assignment Office)
Washington, D.C. 20230
phone: (202) 377-1832

1. Assign frequencies to federal government organizations.
2. Coordinate with the FCC in order to perform long range planning to more efficiently use the U.S.'s allotted frequencies.
3. Prepare for ITU RARCs and WARCs.

An organizational chart of the NTIA is presented as figure 30. The NTIA is program oriented with a staff consisting of a chief administrator, a deputy administrator, three associate administrators, four directors, a chief counsel, a chief scientist and several advisors. The size of the NTIA, including secretarial support, is approximately 60 people [Ref. 33 p. C.3]. All the senior staff and support personnel are organized into seven offices and one institute. The seven offices and one institute cover the subject areas of policy analysis, general counsel, spectrum management, internal affairs, telecommunications sciences, policy coordination and management, public affairs, and media relations.

The Office of Spectrum Management (OSM) performs most of the tasks required by the NTIA, specifically in the area of frequency assignment to government agencies. OSM interacts with the FCC while coordinating the 40% of the allotted frequencies which are jointly controlled. OSM used several planning methods to accomplish its two tasks of satisfying the RF spectrum needs of the federal government and ensuring that the allotted frequencies are being used in an efficient manner. To do this OSM coordinates with all federal agency users to determine their specific needs. [Ref. 32: p. 659]

The NTIA also uses external support in the form of the Interdepartment Radio Advisory Committee (IRAC) and the Frequency Management Advisory Council (FMAC). Both groups fall under the Department of Commerce and are closely tied to the NTIA.

The IRAC was originally created in 1922. In 1970, the present form and mission was established pursuant to Executive Order 11556. The function of the IRAC is to serve in an advisory capacity to the Administrator of the NTIA on matters relating to spectrum management. The IRAC is chaired by and reports to the Deputy Associate Administrator of the OSM. The committee is composed of representatives from each of the federal agencies and departments that use the spectrum. Examples of these representatives include the USN, USAF, USA, VA, Coast guard, NASA, FAA, Commerce, Interior, Justice, etc. A liaison representative from the FCC also sits on the IRAC. [Ref. 33: Append. 9]

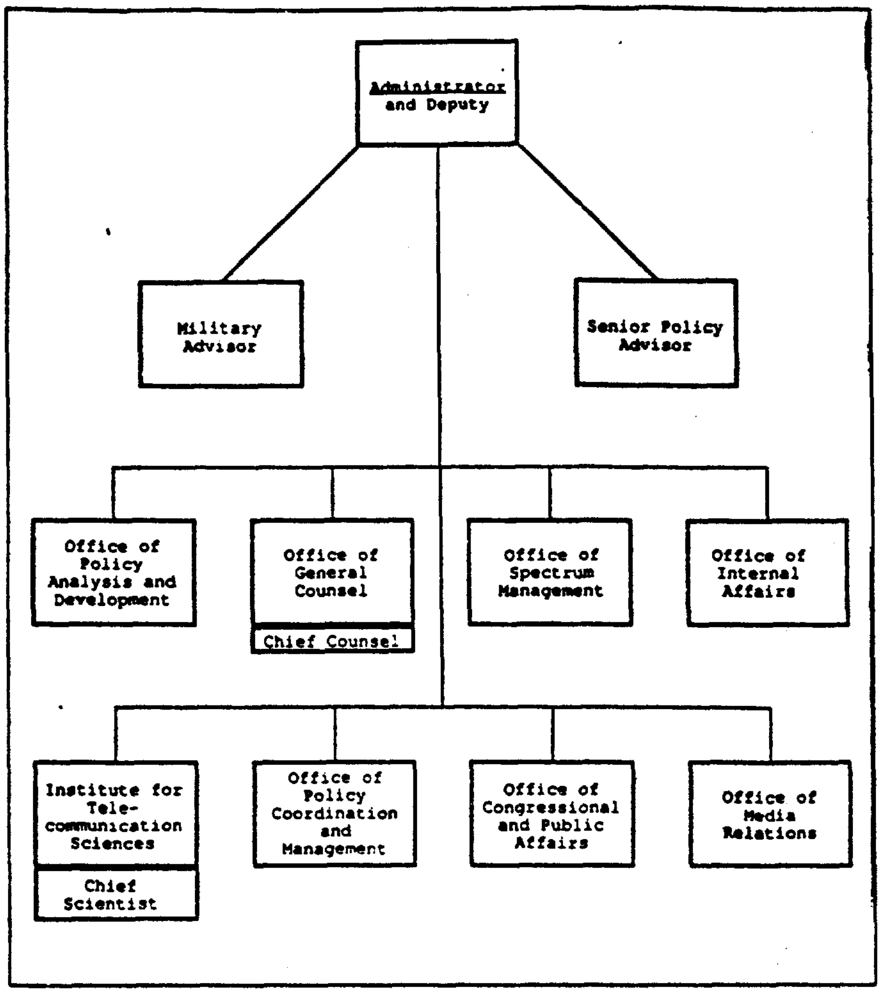
Administrator and Deputy
Military Advisor
Senior Policy Advisor
Office of Policy Analysis and Development
Office of General Counsel
Chief Counsel
Office of Spectrum Management
Office of Internal Affairs
Institute for Tele-communication Sciences
Chief Scientist
Office of Policy Coordination and Management
Office of Congressional and Public Affairs
Office of Media Relations

Figure 30. **NTIA Structural Organization**

The IRAC is a forum in which spectrum management problems are discussed and recommendations formed. This committee meets twice a month. The IRAC is further divided into four subcommittees: the Frequency Assignment Subcommittee (FAS), the Special Planning Subcommittee (SPS), the Technical Subcommittee (TSC) and the International Notification Group (ING).

The other external advisory group the NTIA uses is the FMAC. This council was created in 1965. It is composed of 15 members, who are chosen by the Administrator of the NTIA. The group is chaired by the Associate Administrator of the OSM. The

FMAC meets three time a year. The members of the council are chosen based upon their technical expertise in the telecommunication area of interest. The mission of FMAC is to provide advice to the NTIA on spectrum allocation and the use thereof. More specifically, the members are tasked with reviewing spectrum management programs, reviewing the progress of electromagnetic compatability (EMC) programs, and to prepare the U.S. position on issues to be discussed in upcoming ITU conferences. As an example, the NTIA used the FMAC to make recommendations on the telecommunication aspects of the proposed U.S. space station and on the commercialization of space. [Ref. 32: p. 661]

The complete rules and functions of the NTIA are published in the *Manuel of Regulations and Procedures for Federal Radio Frequency Management*. Copies of this publication may be obtained through the Superintendent of Documents, Washington, D.C. 20402.

The United States recognizes that the portion of the RF spectrum allotted to the U.S., by the ITU, is a precious resource. Such a limited resource cannot be squandered in an ineffective and wasteful manner. Seeing the need to control the use of this resource, the government created an organization to regulate its use. The government also realized that the private and federal sectors operate in vastly different manners. To handle the two separate methods of operation, the frequency regulating organization was structured into two independent organizations. Both must coordinate with each other, and both must report to the higher ITU on a notification basis. Figure 31 attempts to describe this complex relationship in a pictorial form.

Had the decision been made to attempt to obtain a military channel to operate PANSAT, the request for frequency assignment would have been made through the NTIA and its substructure. The Naval Electromagnetic Spectrum Center (NAVEMSCEN), where the request would be initially sent, can be considered part of the NTIA's substructure. Had PANSAT been classified as a strictly experimental satellite, the frequency license application would have been made through the Office of Science and Technology within the FCC's substructure. It was decided to license PANSAT as an amateur Satellite. The license request goes through the FCC and its Private Radio Bureau. The remaining chapters cover procedures to initiate license requests for a satellite in the categories of military, experimental or amateur satellite.

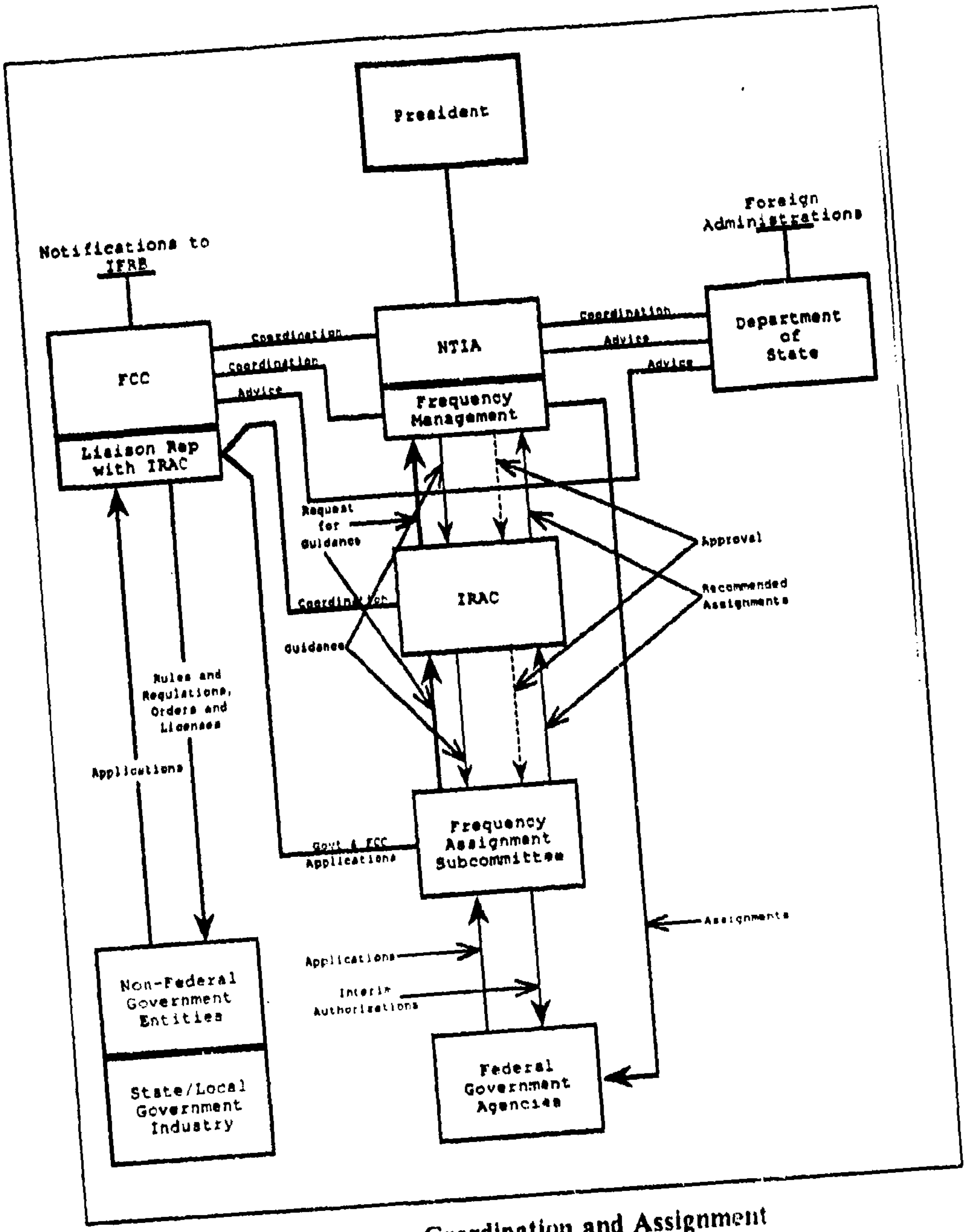

Figure 31. National Frequency Coordination and Assignment

VIII. AMATEUR SATELLITE LICENSING PROCESS

The next three chapters describe the processes involved with licensing a satellite as either an amateur, military or experimental satellite. These three categories were chosen because they are the three categories of radio stations which PANSAT could be classified as.

The first method by which PANSAT could be licensed, is as an amateur satellite operating within the scope of the amateur satellite community. This approach is the method currently pursued by NPS. Part 97 of Ref. 28: defines the Amateur Service as follows:

> A radio communication service for the purpose of self training, intercommunication, and technical investigations carried out by amateurs, that is, duly authorized persons interested in radio technique solely with a personal aim and without pecuniary interest.

The Amateur Satellite Service is defined:

> A radiocommunication service using stations on Earth satellites for the same purpose as those of the Amateur Service.

This section describes aspects involved with the process of obtaining an amateur license, as well as the restrictions imposed on the satellite's operation.

The Federal Communications Commission regulates the amateur frequency bands within the United States. The amateur radio community has been authorized, in ITU region 2, to operate within the portion of the RF spectrum listed in table 4 [Ref. 28: Sect. 97.301].

Table 4. AUTHORIZED AMATEUR FREQUENCY BANDS

BAND	WAVE-LENGTH	FREQUENCY RANGE
MF	160 m	1800-2000 kHz
HF	80 m	3.5-3.75 MHz
HF	40 m	7.0-7.3 MHz
HF	30 m	10.10-10.15 MHz
HF	20 m	18.068-18.168 MHz
HF	15 m	21.00-21.45 MHz
HF	12 m	24.89-24.99 MHz
HF	10 m	28.0-29.7 MHz
VHF	6 m	50-54 MHz
VHF	2 m	144-148 MHz
VHF	1.25 m	220-225 MHz
UHF	70 cm	420-450 MHz
UHF	33 cm	902-928 MHz
UHF	23 cm	1240-1300 MHz
UHF	13 cm	2300-2310 MHz
SHF	9 cm	3.3-3.5 GHz
SHF	5 cm	5.650-5.925 GHz
SHF	3 cm	10.00-10.50 GHz
SHF	1.2 cm	24.00-24.25 GHz
EHF	6 mm	47.0-47.2 GHz
EHF	4 mm	75.5-81.0 GHz
EHF	2.5 mm	119.98-120.02 GHz
EHF	2 mm	142-149 GHz
EHF	1 mm	241-250 GHz

The frequency bands listed in table 4 are a complete list of authorized bands available to the highest amateur license class, the extra class. Lower license classes are more restricted with the portion of the spectrum available for use. The different classes of licenses are covered later in the chapter. ITU Regions I and III, in many instances, provide slightly different frequency ranges for the wavelength bands. For example, use of the six meter band is not authorized for amateurs in Region I, and the use of the two meter band is restricted to 144-146 MHz. In many of the authorized bands, amateurs may use the band on a secondary basis only. This means they are not protected from interference caused by primary users, such as the U.S. government. PANSAT operates in the UHF 70 cm band, with a central frequency of 437.25 MHz. Satellite communications in this band are restricted to 435-438 MHz [Ref. 34: pp. 5.13]. Table 5 lists the authorized frequencies for amateur satellite communications, uplink and downlink [Ref. 28: Sect. 97.207-97.211].

Table 5. AUTHORIZED FREQUENCIES FOR AMATEUR SATELLITES

BAND	WAVE-LENGTH	TELECOMMAND or EARTH-TO-SPACE	SPACE-TO-EARTH
MF	160 m	-	-
HF	80 m	-	-
HF	75 m	-	-
HF	40 m	7.0-7.1 MHz	7.0-7.1 MHz
HF	30 m	-	-
HF	20 m	14.0-14.25 MHz	14.0-14.25 Mhz
HF	17 m to 10 m	All	All
VHF	6 m	-	-
VHF	2 m	144-146 MHz	144-146 MHz
VHF	1.25 m	-	-
UHF	70 cm	435-438 MHz	435-438 MHz
UHF	33 cm	-	-
UHF	23 cm	1260-1270 MHz	1260-1270 MHz
UHF	13 cm	2400-2450 MHz	2400-2450 MHz
SHF	9 cm	3.4-3.41 GHz	3.4-3.41 GHz
SHF	5 cm	5.65-5.67 GHz	5.83-5.85 GHz
SHF	3 cm	10.45-10.50 GHz	10.45-10.50 GHz
SHF	1.2 cm	24.00-24.05 GHz	24.00-24.05 GHz
EHF	6 mm to 4 mm	All	All
EHF	2.5 mm	-	-
EHF	2 mm to 1 mm	All	All

PANSAT has a 1 MHz bandwidth which, when centered on 437.25 MHz, is contained within the authorized band. Sharing requirements for this band are as follows [Ref. 28: Sect. 97.303]:

1. In adjacent ITU regions, frequency bands are allotted to different services of the same category, the basic principle is the equality of right to operate. Operations in one region should not interfere with operations from another region.
2. No amateur station transmitting in the 70 cm band may cause harmful interference to, nor is protected from interference from, the government radiolocation service.
3. In Region II, the 430-440 MHz is allotted to amateurs on a secondary basis. As such, they cannot cause interference to any other nation's radiolocation services.

Within each frequency band, amateurs are restricted in the types of emissions which are authorized. Table 6 summarizes the authorized emission types [Ref. 28: Sect. 97.305]. Continuous Wave (CW) transmissions, also called International Morse Code, is authorized in any band. In table 6, RTTY is a narrow-band telegraphy emission. Data is computer communications emissions. Modulated Continuous Wave (MCW) is tone modulated morse code. Phone emissions are speech and other sounds. Image emissions include television or facsimile. SS stands for spread spectrum communications. Test is an emission with no information, and lastly, pulse is a special type of three symbol emission.

Table 6. AUTHORIZED AMATEUR EMISSION TYPES

BAND	WAVELENGTH	EMISSION TYPES AUTHORIZED
MF	160 m	CW, RTTY, data, phone, image
HF	80 m	CW, RTTY, data
HF	75 m	CW, phone, image
HF	40 m	CW, RTTY, data, phone, image
HF	30 m	CW, RTTY, data
HF	20 m to 10 m	CW, RTTY, data, phone, image
VHF	6 m to 1.25 m	CW, RTTY, data, MCW, phone, image, test
UHF	**70 cm**	**CW, MCW, phone, image, RTTY, data, SS, test**
UHF	33 cm	CW, MCW, phone, image, RTTY, data, SS, test, pulse
UHF	23 cm	CW, MCW, phone, image, RTTY, data, SS, test
UHF	13 cm	CW, MCW, phone, image, RTTY, data, SS, test, pulse
SHF	9 cm to 5 cm	CW, MCW, phone, image, RTTY, data, SS, test, pulse
SHF	3 cm	CW, MCW, phone, image, RTTY, data, SS, test
SHF	1.2 cm	CW, MCW, phone, image, RTTY, data, SS, test, pulse
EHF	6 mm to 1 mm	CW, MCW, phone, image, RTTY, data, SS, test, pulse

PANSAT uses a direct sequence spread spectrum communications system. Referring to table 6, spread spectrum is an authorized emission type in the 70 cm UHF band.

The FCC has placed a number of restrictions on the use of spread spectrum communications. Spread spectrum communications cannot be used to encode a message so that no one else can read it. The purpose must be to facilitate communications. To comply, NPS is required to make such things as schematics of PANSAT's encoder/decoder circuit boards public so that all interested amateurs may use the asset. These descriptions may be published in periodicals such as Orbit Magazine or the Amateur Satellite Report newsletter. The non-cipher rule does not apply to the telecommand portion of the transmission. The purpose here is to protect the security of the satellite. Spread spectrum emissions are only authorized in locations where the amateur service falls under the domain of the FCC. This is in the continental United States in ITU Region II. It is unauthorized to transmit a spread spectrum signal across international borders. The use of spread spectrum emissions also means that the satellite cannot be the cause of harmful interference to other authorized users. PANSAT is also not protected from harmful interference caused by authorized users. Hybrid spreading techniques are not authorized. PANSAT cannot combine the frequency hopping and direct sequence spreading techniques. Only spreading sequences from the output of one binary linear feedback shift register are authorized. The shift register output sequence cannot be altered before use. The peak power output cannot exceed 100 W. When ordered by the FCC, PANSAT must be able to cease transmissions, restrict transmissions, or produce a record which may be converted to the original message for all spread spectrum transmissions. [Ref. 28: Sect. 97.311 and 97.419]

Station records must document all spread spectrum communications. The records should contain information sufficient to allow the FCC to decode all transmitted information. The records must be retained for one year after the last transmission. The following information, as a minimum, should be included in the records [Ref. 34: p. 243]:

1. A technical description of the transmitted signal.
2. Parameters describing the transmitted signal, such as frequency, chip rate, code rate, spreading function, transmission protocol to include the method of achieving synchronization and type of modulation.
3. Type of information, such as voice, data, television, facsimile, etc.

4. The method and frequency used for station identification.
5. The date time group of the beginning and ending of each transmitted signal.

Perhaps the first step in licensing a satellite is obtaining an individual amateur operator's license. There are five classes of amateur licenses. Table 7 lists the classes of licenses, the number of words per minute (WPM) required to be able to pass or receive in the morse code test, the content of the written exam, and the privileges allotted to each class [Ref. 34: p. 2.2].

Table 7. AMATEUR OPERATOR LICENSE CLASSES

CLASS	MORSE CODE TEST	WRITTEN EXAM	PRIVILEGES
Novice	5 WPM	Elementary theory and regulations	CW on 3700-3750, 7100-7150, and 21,100-21,200 kHz: CW & RTTY on 28,100-28300 KHz: CW & SSB voice on 28,300-28,500 KHz: All modes on 222.1-223.91 MHz and 1270-1295 MHz
Technician	5 WPM	Novice plus technician level theory and regulations	All amateur privileges above 50 MHz plus Novice HF privileges
General	13 WPM	Technician plus general theory and regulations.	All amateur privileges except those reserved for Advance and Extra
Advanced	13 WPM	General plus intermediate theory	All amateur privileges except those reserved for Extra
Extra	20 WPM	Advance plus special exam on advanced techniques	All amateur privileges, frequencies listed in table 4

All satellites launched into the amateur service must have a sponsor or trustee, who is responsible for the proper operation of the satellite. The sponsor/trustee must hold a valid amateur extra class license [Ref. 28 : Sect. 97.407]. At NPS, a permanent faculty member seemed the best person to be PANSAT's sponsor/trustee. Professor R.W. Adler, who is currently upgrading his advanced license to an extra class license, is PANSAT's sponsor/trustee. Any other persons wishing to operate the satellite and utilize its communications capability must hold at least a technician class license [Ref. 34: p. 5.13]. Referring to table 7, a technician class license is required to use the 435-438 MHz UHF band. It would be wise for several NPS SSAG staff members to obtain amateur licenses to increase the flexibility of PANSAT's operating schedule.

The first step to either upgrade a license or to obtain a novice license is to fill out an FCC form 610. Call or write the FCC local office to obtain FCC form 610 originals. A copy of this form is provided as Appendix A. Perspective licensees are required to take both a morse code capability test and a written examination. The content of the two types of exams are contained in table 7. Testing is performed by accredited Volunteer Examiners (VEs). VEs fall under the American Radio Relay League's (ARRL) Volunteer Examiner Coordinators (VECs). Testing is performed at thousands of locations throughout the country. [6]

After the completion of the exams, the VECs forward the application and test results to the FCC's Gettysburg, Pa. office within ten days. The FCC sends the individual the amateur class license on an FCC form 660. Figure 32 shows an example of an FCC form 660. A copy of FCC form 660 must be maintained by the operator when transmitting

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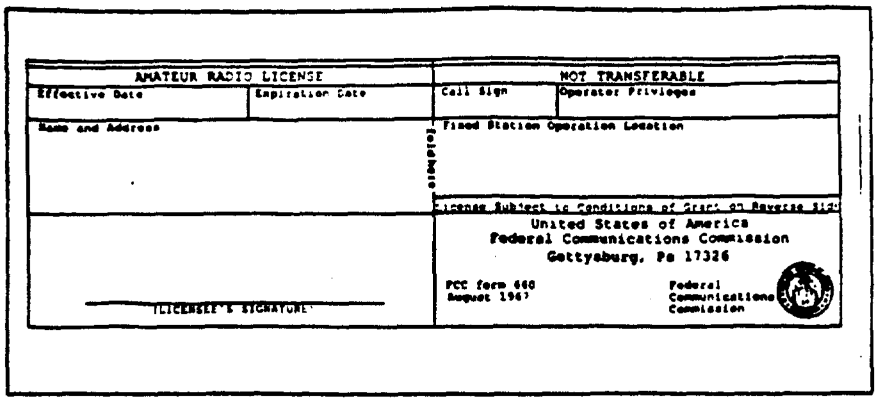
[6] The ARRL/VEC can provide information on exam locations. Their address is:

ARRL Headquarters
ARRL/VEC Division
225 Main Street
Newington, Ct. 06111



AMATEUR RADIO LICENSE

NOT TRANSFERABLE

Effective Date

Expiration Date

Call Sign

Operator Privileges

Name and Address

Fixed Station Operation Location

License Subject to Conditions of Grant on Reverse Side

United States of America
Federal Communications Commission
Gettysburg, Pa 17326

FCC form 660
August 1967

Federal Communications Commission

(LICENSEE'S SIGNATURE)

Figure 32. Amateur License, FCC form 660

signals. Should someone fail either portion of the examination, there is no waiting period for a retest [Ref. 34: pp. 2.1-2.14]. Licensing procedures and license classes for the amateur service have continued to change ever since the first license was issued in 1912. There is no reason to believe this evolution will not continue. Present licensing procedures could be obsolete in a few years time. Examine current sources for the present requirements.

In conjunction with an operator's license, a station license is also required. In most instances, the station license is obtained at the same time as the operator's license. This is accomplished by completing the pertinent parts of FCC form 610. When the operator's license arrives, the station license is also listed on the FCC form 660, as depicted on the right portion of figure 32. The FCC used to issue licenses for Club or Military Recreation Stations such as K6LY, the club station located at NPS. The Commission has since decided not to issue any new club station licenses, however, the FCC will renew any old club station licenses on FCC Form 610B [Ref. 34: p. 4.10]. A copy of FCC form 610B is included as Appendix B. NPS plans to initially use the NPS club station, located at building 205 of the La Mesa housing complex, until a new ground station can be constructed on the NPS campus. One suggested location is on the roof of Spannagel Hall.

Since no new club stations are being issued, a station trustee must be appointed. Professor Addler is the designated trustee for NPS's ground station. The station uses the trustee's call sign. An FCC form 610 (see Appendix A) is used to renew the trustee license, or in this case change the individual station address. Presently, licenses are valid for a period of ten years. [Ref. 28: Sect 97.59]

When building a radio station, or more specifically putting up an antenna, another federal agency called the Federal Aviation Administration (FAA) often becomes involved. This is especially true if the antenna is to go up near an airport, as is the case with the Monterey Airport. If the antenna structure is more than 200 feet above the ground, FCC form 854 must be filed with the Commission and FAA form 7460-1 must be filed with the FAA. FCC form 854 and FAA form 7460-1 are provided as Appendices C and D, respectively. To obtain FCC form 854, contact the FCC local office. To get FAA form 7460-1, contact the FAA's regional office. [7]

If the antenna structure is near a runway greater than 3250 feet in length, the station must be within a glide slope of 100 to 1 in order to avoid filing forms 854 and 7460-1. To figure the highest possible height of the antenna structure without filing the two forms, determine the distance to the closest runway. This value is approximately 5000 feet. So $\frac{5000 \text{ ft}}{100/1 \text{ glideslope}} = 50$ ft, which is the highest tower which can be constructed without filing [Ref. 34 : pp. 3.1-3.5]. However, if the antenna is constructed on the roof of a preexisting structure, an antenna of less than 20 feet in height may be constructed and be exempt from the above rules. The rule states that a 20 foot grace distance is allowed for antennas above ground, other natural features, or manmade structures excepting an antenna tower [Ref. 34: p. 3.5]. Should an antenna go on the roof of Spannagel, the six stories of Spannagel would provide ample elevation to avoid disruption of the link path to the satellite. There should be no reason to raise the antenna more than 20 feet above the roof. If it is deemed necessary to have an antenna higher than 20 feet, on Spannagel or elsewhere, the above rules and filings would then apply.

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[7] The address of the FAA's Western Pacific Regional Office is:

Western Pacific Regional Office
Air Traffic Division
15000 Aviation Blvd
Hawthorne, Ca. 90260
phone: (213) 297-1182

In most cases, city and local government also get involved with antenna construction. The federal government has protected the rights of amateurs to construct antenna towers. This protection is found in *Amateur Radio Preemption* 101 FCC2d 952 (PRB-1) of 19 September 1985. This document reinforces the right to build a tower of reasonable height. The determination of 'reasonable,' however, is left up to the local government's interpretation [Ref. 34: p. 3.8]. It is a good idea to obtain a copy of the local zoning ordinances. These can be found at City Hall. These regulations describe the uses and dimensional requirements of structures constructed in specific city zones. Once a permit is obtained through city government, the local building inspector inspects the tower to determine if it is safe [Ref. 34: p. 3.11]. For the NPS case, most, if not all, of the municipal interaction is performed by NPS officials and not SSAG members. The SSAG, however, has to convince the NPS officials that such construction is needed.

Once the operator's license and the station license are taken care of, it is time to notify the FCC of the intended satellite operation. Two pre-space operation notifications are required by the FCC prior to launch.

The first pre-space notification must be submitted within 27 months of the anticipated launch date. Presently PANSAT's anticipated launch date is in July 1992. The first notification, therefore, needs to be submitted to the FCC in May 1990. The first notification must provide information as required by Appendix 4 of the *ITU Radio*

Regulations and Resolution No. 642 of the same [Ref. 28: Sect. 97.207]. Appendix 4 is a good guide to follow while writing the first notification. Resolution No. 642 of Ref. 35 recognizes the following factors [Ref. 35: Res. 942]:

1. Characteristics of earth stations in the amateur service vary widely.
2. Space stations are intended for multiple use.
3. Coordination between amateur sites is accomplished without formal procedures.
4. The burden of terminating harmful interference falls upon the authorizing administration (the FCC in this case).

Recognizing these factors about the amateur service, Resolution No. 642 says that not all the information specified as required in Appendix 3 and 4 of the Radio Regulations apply to the amateur service. As such, only applicable information in the two appendices need be filed. As an example of a first pre-space notification, Appendix E contains the notification sent to the FCC for PANSAT. In general, pre-space notifications consist of the space operation date, the satellite service area, orbital parameters and technical characteristics for both uplink and downlink.

A second pre-space notification is required to be sent to the Commission no later than five months prior to intended launch. PANSAT's second notification must be filed during February 1992. This notification must supply information as required by Appendix 3 and Resolution No. 642 of the ITU Radio Regulations [Ref. 28: Sect. 97.207]. The second notification is much like the first, but requests more detail. Appendix 3 of the Radio Regulations is also an excellent guide to follow when drafting the notification An example of a second pre-space notification is provided as Appendix F.

Prior to September 1989, three pre-space notifications were required at intervals of 27 months, 15 months and 3 months prior to launch. The FCC has been attempting to make satellite communications a bit easier. This is an example of that effort. [Ref. 36: Sect. 97.423]

Once the satellite has been launched and has started to transmit, a written in-space notification must be submitted to the FCC within 7 days of the commencement of satellite operations. The in-space notification is actually a resubmission of the second notification with all pertinent updates, such as the actual orbital parameters and any last minute changes. [Ref. 28: Sect. 97.207 and Ref. 34: p. 232]

The final notification required by the FCC is the post-space notification. The post-space notification is simply a written letter to the Commission stating the termination of space operations and signal transmission. The date time group of actual termination should be included in the notification. The post-space notification must be submitted within three months after space operations terminate. If the FCC had ordered a cessation of signal transmissions, then the post-space notification is required within 24 hours of termination. [Ref. 28: Sect. 97.207 and Ref. 34: p. 252]

Through what offices do the notifications travel? Each notification, once compiled and checked for correctness, should be sent to the Private Radio Bureau, FCC, Washington, D.C. 20554. When the Private Radio Bureau of the FCC receives the notification, it is forwarded to the Frequency Liaison Branch, who logs the notification in. This branch reviews it and forward the notification to the Treaty Branch. The Treaty Branch checks it for correctness, as pertaining to international treaties and ITU requirements. If there are no discrepancies, a copy is filed and the original, with an FCC cover sheet, is forwarded to the IFRB of the ITU. The IFRB looks for possible international conflicts. Before filing the notification, it is a good idea to call the FCC Treaty Branch (Mr. Frank Williams is the present Treaty Branch Chief, phone: (202) 653-8126) to critique the notification over the phone to avoid delays in processing.

Should the IFRB decide that there are no conflicts, the IFRB publishes the information contained in the notification in their weekly circular, of which the U.S. state department receives a copy. The organization requesting satellite licensing does not receive a direct acknowledgement from either the ITU or the FCC. The FCC only contacts the perspective licensee if there is a problem with the notification. The only way to discover if a satellite has the 'go ahead' is to monitor the ITU's weekly circular. The FCC also retains a copy of the weekly circular, so verify with them when the satellite's ITU notification is anticipated. A normal delay time from the initial filing to the ITU's publication of the notification is from five to six months. [Ref. 37]

IX. FEDERAL AGENCY SATELLITE FREQUENCY ASSIGNMENT

Another method in which PANSAT could obtain a frequency channel is through the NTIA instead of the FCC. The NTIA manages the frequency spectrum for those frequencies allocated to the federal government. NPS falls under the Department of the Navy, a governmental organization, and should be eligible for consideration to obtain a federally allotted frequency.

NPS must first go through naval channels to initiate such a request. The request would go to the Naval Electromagnetic Spectrum Center (NAVEMSCEN) in Washington, D.C. The phone number for the allocation division is (202) 282-2421, and the number for the assignment division is (202) 282-2427. The Navy coordinates with the NTIA to fulfil the request.

The NTIA does not use the same process as the FCC. Licenses are not issued. Instead, a two step process is used. First the requesting organization must request a frequency allocation. A frequency allocation, as pertaining to the naval service, is defined:

> The acknowledgement by the Chief of Naval Operations (CNO) that development and/or procurement of C-E equipment can be supported for operation on a specific frequency or band of frequencies within the radio frequency spectrum. [Ref. 38: p. 2]

The Navy wishes to save money on the development of a system which causes harmful interference to an already existing system, resulting in the cancellation or restriction of one of the two programs. The second step, after obtaining a frequency allocation, is to request a frequency assignment. A frequency assignment is defined:

> The discrete frequency or frequencies on which C-E equipment or a system is authorized to operate within its allocated band at the location(s) designated and within the constraints of the authorizing assignment. [Ref. 38: p. 2]

The Administrator of the NTIA is the ultimate authority for managing frequency use of DOD entities within the U.S.. The Department of Defense defines spectrum management as follows:

> The function where use of the radio frequency spectrum is controlled to ensure the electromagnetic compatability of communications-electronics systems. Requirements for use of the radio frequency spectrum are presented, reviewed, and, to the degree possible, satisfied for communications-electronics systems being acquired or brought into use. [Ref. 39]

Frequency management within the Department of the NAVY (DON) is performed by five categories of organizations: sponsors, managers, developers, users and coordinators.

A spectrum sponsor makes policy, provides project funding and gives overall leadership and direction in the area of spectrum management. The office of the CNO is a sponsor. The CNO is primarily interested in the authorization for frequency allocation issue. The assignment function is performed by the managerial category. To accomplish its spectrum management tasks, the office of the CNO coordinates with other governmental agencies through various spectrum management forums in order to ensure system compatability. As such, the CNO is responsible for all DON spectrum management and for the Electromagnetic Compatability programs (EMC). [Ref. 40 Par. 01.03.0200]

A spectrum manager is responsible to ensure the most efficient use of the RF spectrum. The Director of NAVEMSCEN performs the managerial tasks which assist the CNO with the allocation function, but is also concerned with the assignment function. NAVEMSCEN authorizes frequency assignment applications after assuring electromagnetic compatability. NAVEMSCEN also participates with all levels of spectrum management (such as DON, DOD, allied, etc.) to develop management policy and promote spectrum harmony. [Ref. 40: Par. 01.03.0300]

Developers design and construct the electromagnetic systems that are needed to accomplish the mission of the Navy. The Chief of Naval Material (NAVMAT) fills these requirements. NAVMAT is responsible for all aspects of research and development of new radiating systems, short of actual authorization for assignment and allocation. [Ref. 40: Par. 01.03.0400]

Spectrum users install and operate electromagnetic systems for the purpose of fulfilling their respective missions. The operational forces of the USN and USMC are the spectrum users within DON. They are responsible to control the military use of frequencies within their area of responsibility (AOR). This includes maintaining records showing their use of frequencies. Users attempt to resolve any conflicts on the user level to the best of their ability. Failing a solution, the conflicts are forwarded up the chain of command for resolution. [Ref. 40 : Par. 01.03.0500]

Coordination is performed by Area Frequency Coordinators (AFCs). AFCs exist on a regional level and resolve frequency management conflicts within their region. There are two levels of AFCs: service level and DOD level. [8]
AFCs also coordinate with nonmilitary organizations in the region to resolve conflicts involving other governmental agencies or civilian organizations. [Ref. 40: Par. 01.03.0620]

An application for frequency allocation should be submitted as early as possible, via the chain of command, when the intended use and frequency requirements are first known. The ultimate destination of the application is the office of the CNO. The CNO coordinates with the NTIA through the Navy's membership on the Interdepartment Radio Advisory Committee (IRAC). The CNO uses this forum to make sure that all prospective space systems are compatible with existing and planned systems [Ref. 38: p. 4]. The application should be made utilizing a DD form 1494. A copy of DD form 1494 is provided as Appendix G. For space systems, the review and approval process takes considerable time, from four to six years [Ref. 40: Par. 01.0C.0320]. As an example, FLTSATCOM required seven years to obtain a frequency allocation [Ref. 41]. Annex C of Ref. 40 provides clear step by step directions for completing the complicated DD form 1494.

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[8] The naval AFC in NPS's region is:

Navy Frequency Coordinator
Western United States
Point Magu, Ca. 93042

If the Department of the Navy were funding PANSAT through the standard Navy acquisition system, no major funds would be granted to the project until a frequency allocation has been obtained [Ref. 40: Par. 01.0C.0100]. Ref. 40 provides a twelve step process which should be followed to facilitate the approval of a frequency allocation application. Figure 33 provides a flowchart of the twelve step process [Ref. 40: Par. 01.0C.0220]. A more thorough description of the process follows [Ref. 40: Par. 01.0C.220]:

1. **Identify the mission:** Define the needs of the system and the overall system capabilities.
2. **Determine requirements:** Relies upon the specific functions the system must fulfil, such as communications, navigation, ECM, etc.
3. **Identify implications:** Conduct an overview of requirements and compare with the state of present technology. Assess if this overview leads to the best suited frequency ranges.
4. **Determine allocation:** Identify the potential frequency bands in which the system could operate.
5. **Electromagnetic environment study:** Consider all the users of the chosen frequency band and conduct a study to determine if the new system will interfere.
6. **Frequency band selection:** Complete DD form 1494 and forward through the chain of command to the CNO.
7. **Frequency allocation application:** Complete DD form 1494 and forward through the chain to CNO OP-941F.
8. **Intermediate headquarters action:** Each addressee reviews the application for accuracy and technical content, writes a recommendation and forwards to the next addressee.
9. **Review:** The CNO and NAVEMSCEN review the validity of the application, its EMC considerations and technical aspects. NAVEMSCEN makes its recommendation to the CNO.
10. **Coordination:** CNO validates the requirement, then coordinates with other services through his membership on the U.S. Military Communications and Electronics Board (USMCEB) and for space systems, with the NTIA through the IRAC.

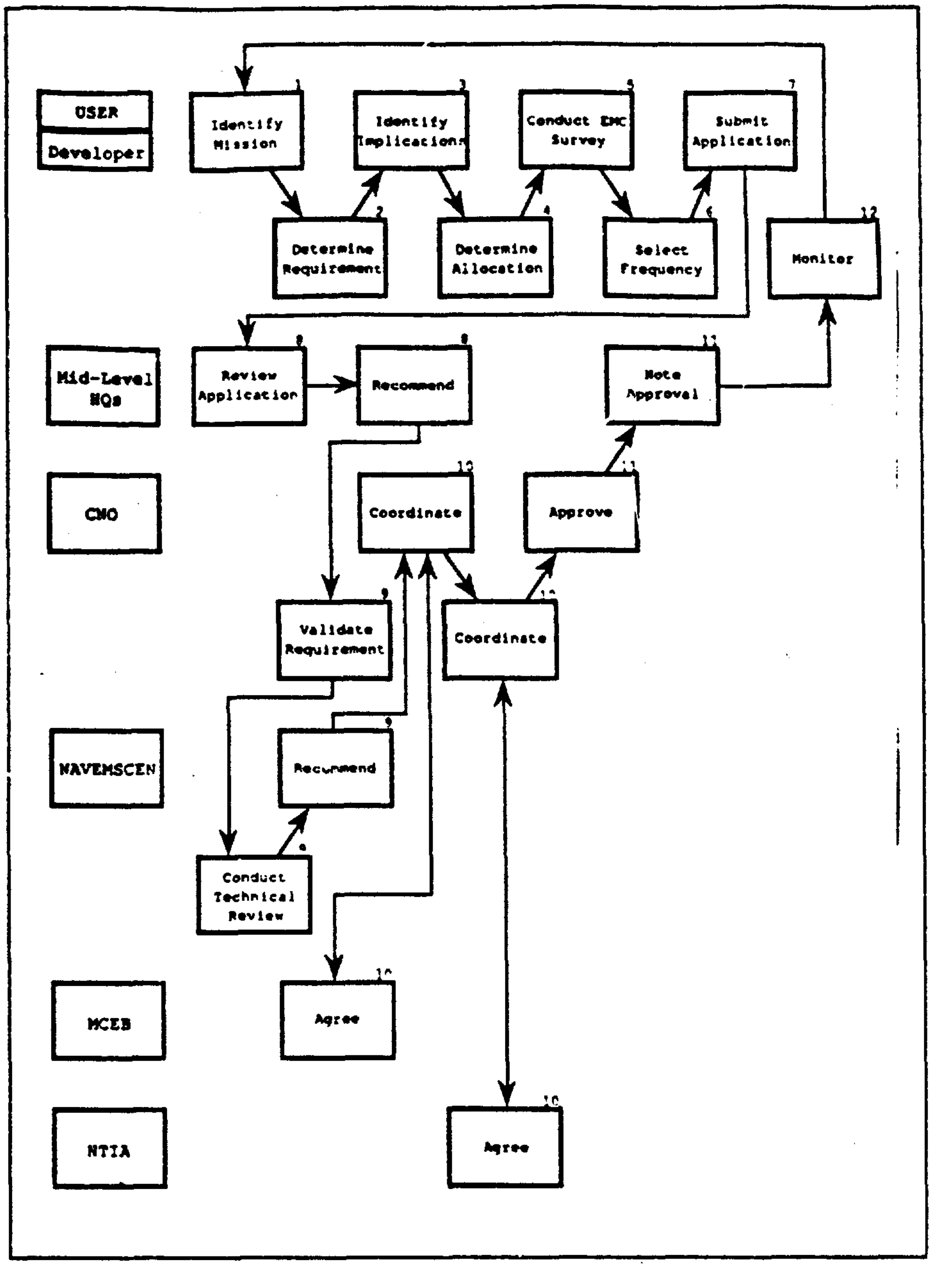


Figure 33. Frequency Allocation Application

11. **Approval:** After all requirements are met and all coordination accomplished, the CNO approves the application and informs the request originator.

12. **Monitor:** Monitor changes which may occur with the system. A new DD form 1494 must be submitted to change the allocated frequency band.

Table 8 provides a list of frequencies in the UHF/VHF bands which are allotted to the federal government [Ref. 42: pp. 4.43-4.52]. Table 8 shows that PANSAT's desired frequency of 437.25 MHz is not slotted for governmental use, but is designated for amateur service. It is possible that 437.25 MHz may still be used if technical justification can be provided that this is a needed resource and that frequency is optimal. The technical justification must also show that the system will not cause harmful interference to authorized users of the band [Ref. 38: p. C.1]. The CNO can grant a waiver to use the desired frequency after proper coordination with the appropriate services, the FCC in this instance. Other options include moving PANSAT's operating frequency to the 225-400 MHz band, which is already allotted to military space operations. Another possibility is to operate outside the UHF band, where other frequencies are allotted to space research and operations. These frequencies are 137 MHz in the VHF band or 7-8 GHz in the SHF band.

Table 8. UHF/VHF GOVERNMENTAL FREQUENCY ALLOCATIONS

BAND	FREQUENCY	GOVERNMENT ALLOCATION
VHF	137-138 MHz	(*)Meteorological Satellite, Space Operation, Space Research
	138-144	Fixed/Mobile
	144-148 MHz	-
	148-149.9 MHz	Fixed/Mobile
	149.9-150.05 MHz	(*)Radionavigation-Satellite
	150.05-150.8 MHz	Fixed Mobile
	150.8-162.0125 MHz	-
	162.0125-173.2 MHz	Fixed/Mobile
	173.2-173.4 MHz	-
	173.4-174 MHz	Fixed/Mobile
	174-216 MHz	-
	216-220 MHz	(*)Maritime/Mobile
	220-225 MHz	(*)Fixed Mobile
	225-328.6 MHz	Military-Satellite
UHF	328.6-335.4	(*)Aeronautical Radionavigation
	335.4-399.9 MHz	Military-Satellite
	399.9-400.05 MHz	(*)Radionavigation-Satellite
	400.05-400.15 MHz	(*)Standard Frequency and Time Signal Satellite
	400.15-401 MHz	(*)Space Research, Meteorological-Satellite, Space Operation
	401-401 MHz	(*)Space Operation
	402-406 MHz	(*)Meteorological Aids
	406-406.1 MHz	(*)Mobile-Satellite
	406.1-410 MHz	Fixed Mobile, (*)Radio Astronomy
	420-450 MHz	Radiolocation
	450-460 MHz	-
	460-470 MHz	Meteorological-Satellite
	470-512 MHz	-

Note an (*) indicates use on a shared basis with non-governmental users. Before any radiating equipment can be operated in the military service, both a frequency allocation and a frequency assignment are required. Frequency assignments should be initiated soon after the allocation application is approved and the test site data is known. The frequency assignment request is sent in standard message format called the Standard Frequency Action Format (SFAF). The SFAF is sent through the Navy AFC, at Point Magu, to NAVEMSCEN. NAVEMSCEN is responsible for the approval of frequency assignments [Ref. 38: pp. 3-5]. The latest date at which an SFAF can be sent and approved is 90 days prior to the actual operation date [Ref. 40: Par. 01.0D.0204]. Annex D of Ref. 40 has the appropriate formats and codes for SFAFs of various system types. The pertinent SFAF entries which apply for earth-to-space and space-to-earth systems are included in Appendix H [Ref. 40 pp. D.43-D.44]. An example of a completed message for PANSAT in the Earth-to-space direction is also provided in Appendix H. An additional SFAF would be required to be sent for the space-to-earth direction.

The most important factor considered when CNO and NAVEMSCEN allocate and assign frequencies, respectively, is Electromagnetic Compatability (EMC). EMC is defined as follows:

> The condition that prevails when telecommunications equipment is performing its individually designed function in a common electromagnetic environment without causing or suffering unacceptable degradation due to unintentional electromagnetic interference to or from other equipment in the same environment. [Ref. 40: Par. 01.0A.0100]

An EMC survey must be performed by the requesting organization prior to submitting the frequency allocation request. The results of the EMC survey are included with the submission of the DD form 1494.

The string of organizations through which the application forms must travel is extensive. The first application to ascend the chain is the DD form 1494. The DD form 1494 journeys through all the intermediate headquarters and eventually arrives at the CNO's office. The CNO sends the request to the USMCEB. Through the IRAC, the CNO coordinates with the NTIA and the FCC. At the USMCEB, the J12 working group assesses the request and gives it a J12 code. The J12 code is an entry on the SFAF, used when requesting a channel assignment within an allocated frequency band. The request next goes to the NTIA and the national level. The Spectrum Planning Subcommittee, a working group of the IRAC, examines the request and approves it. Once approved, the Satellite Systems Group (SSG), another working group of the IRAC, study the request. This group requires an advance notification, which follows the format of Appendix 4 of the ITU Radio Regulations. This notification is identical to the first pre-space notification filed under amateur rules. If the frequency band is shared with other nations, a notification following Appendix 3 of the ITU Radio Regulations is also required. This is identical to the amateur second pre-space notification. Once the SSG approves the request, the application goes to the international level. The advanced notification(s) is forwarded through the U.S. State Department to the IFRB in Geneva. The IFRB looks for possible international conflicts. Barring none, the IFRB publishes the notification in the ITU weekly circular. The allocation application is now finally approved. The entire process can take six years to accomplish for a satellite system. [Ref. 41]

Once the frequency band is allocated, it is much easier to get a channel assignment within the allocated band. The SFAF message is sent, via the AFC, to NAVEMSCEN. With some coordination along the way, NAVEMSCEN can usually approve the assignment request within three months. If the frequency is in a military only band, such as 225-400 MHz, the assignment request is sent up to the USMCEB for approval. Within the geographical area of operation, the frequency proposal is done in coordination with the area commander, such as CINCPACFLT. Should other conflicts be foreseen, coordination may also have to be done with the Allied Radio Frequency Board in Brussels, or with the Combined Communication Electronics Board, which is comprised of english speaking nations. [Ref. 41]

The military satellite frequency band from 225 to 400 MHz is a very crowded band. A wide variety of systems use that particular band. As a result, it is often difficult to obtain an operational frequency assignment in that band. It is easier to get an experimental military frequency assignment. Experimental assignments are only valid for two years. Since PANSAT's design life is under two years, such an assignment fulfils PANSAT's needs. The procedure for getting such a frequency assignment is identical to obtaining an operational assignment, except the project is denoted as being in stage 1 on the DD form 1494. Another solution to the crowded 225-400 MHz band problem is to use another band, such as 7-8 GHz, provided it satisfies PANSAT's requirements. [Ref. 41]

Classified satellites do not have to endure this allocation and assignment process. It makes no sense to have the ITU publish the advance notification of a U.S. black system. These satellites, however, are not afforded protection from harmful interference. Hostile nations may jam them at will without facing international rebuke (in public at least).

While the governmental route of obtaining a frequency channel for PANSAT is available, the quickest method is to proceed via the amateur route. The amateur license process requires 27 months of lead time, as compared to six years through the naval process. The desired 437.25 MHz is also not allocated for government use. There is much more paperwork, including an EMC survey, and the application must survive several boards. With a military channel, however, there is a much smaller emphasis on operator qualifications. It is also easier to make contacts within the DON, so as to keep appraised of the request status. This allocation process is possible, but should be used only if the amateur process should fail. Should PANSAT use a communications system which has already gone through the allocation process, it may be possible to bypass the long allocation process, or at least part of it, and proceed directly to the assignment phase. Using an experimental frequency assignment designator should also speed up the process. The amateur approach seems best suited for PANSAT, but for a more complex system, in which restricted satellite access is desirable, the federal license approach may be better suited.

X. EXPERIMENTAL SATELLITE LICENSING

Another way to license PANSAT is as an experimental satellite. This experimental satellite uses a different approach than for a military experimental satellite. The filing is done under Part 5 of Ref. 28. To utilize a Part 5 filing, NPS would have to convince the FCC that NPS's SSAG was not acting as an entity of a federal agency or department. As a federal agency, NPS would be required to use the military experimental route discussed in the previous chapter. [Ref. 43]

The Experimental Radio Service is defined as follows:

> A service in which radio waves are employed for purposes of experimentation in the radio art or for purposes of providing essential communications for research projects which could not be conducted without the benefit of such communications. [Ref. 28: Sect. 5.3(c)]

PANSAT could be described nicely by this definition. In the experimental service's scope of service there are several types of operations listed. Two of the listed operations could apply directly to PANSAT [Ref. 28: Sect 5.202]:

1. Experimentations in scientific or technical radio research.
2. Communications essential to a research project.

The spread spectrum communications system satisfies the first operation type and PANSAT's experimental payload is of the second type.

Filing under part 5 for a space based radio station is done in the same manner as for an earth based station. The licensee must be a qualified radio operator able to make necessary transmitter adjustments. The licensee is also responsible to ensure that all operators are so qualified [Ref. 28: Sect. 5.155]. Station authorizations in the experimental service are granted only to qualified individuals whose experiment fulfils one of the two scope of service types as listed in the previous paragraph.

Any frequency listed in the Table of Frequency Allocations (an extensive table in Part 2 of Ref. 28), both governmental and nongovernmental, but excluding the amateur band, may be used by the Experimental Radio Service if it is deemed available for such service [Ref. 28: Sect. 5.203 and Ref. 43]. PANSAT's frequency of 437.25 MHz is in the amateur band and therefore is not available for use in this service. All experimental radio frequencies are to be utilized on a secondary or sharing basis. As such, the experimental systems cannot cause harmful interference to authorized users. Other general restrictions limit transmission times to the minimum time practical to complete the mission. Radiated power is also limited to the lowest practical value. Licensees are authorized to transmit only when necessary and directly related to the experiment. [Ref. 28: Sect. 5.151]

The experimental license is good for a period of two years. Each of the experimental stations are required to maintain written records of operation for a period of one year after a transmission. The content of the station records should include [Ref. 28: Sect. 5.163]:

1. Date time group of the operation.
2. Frequencies used.
3. Power.
4. Emission type.
5. A chronological record of experimentation conducted.
6. Operator's name and signature.

The Commission does not require a report containing the results of the experiment.

To apply for a license to construct and operate a station in the experimental service, FCC form 442 is used. A copy of FCC form 442 is provided as Appendix I. A separate FCC form 442 is required to be submitted for each station. PANSAT requires two such applications, one for the ground station and one for the satellite. Applications need to be submitted to the FCC at least 60 days prior to the date of anticipated operations. Should PANSAT exceed a two year lifetime, it would be necessary to apply for a license renewal. This is done with an FCC form 405. A copy of FCC form 405 is provided as Appendix J. Only one FCC form 405 need be submitted for the entire system. [Ref. 28: Sect. 5.55] These forms should be sent to the Frequency Liaison Branch of the FCC, at their Washington office. The license is processed through the Office of Science and Technology.

The amateur license approach is a more attractive option than the experimental route. First and foremost, it would be most difficult to convince the FCC that the SSAG was not acting as an entity of the federal government, the DON specifically. The desired frequency band of 435-438 MHz could not be made available for experimental use. The two year time limit does not provide for much flexibility, although an extension may be requested. The numerous operational restrictions would limit PANSAT's availability as a teaching tool. However, the 60 day lead time is the smallest of all the services discussed. Depending upon the FCC's perception of NPS's SSAG, federal or not, the experimental service presents a viable licensing option.

XI. FINAL COMMENTS

This thesis began by examining general design considerations for any satellite and specific design considerations for PANSAT and its different systems. The design process was found to be a most complex exercise in which many seemingly unrelated tasks are woven together to create an operational satellite. 'Operational' is the first key adjective. The ultimate goal of every satellite and each of its subsystems is to be operational. Before any design questions can be answered, the intended mission of the space system has to be determined. All subsequent design strives to fulfil the stated mission requirements in an affordable manner. The second important adjective is 'affordable,' or stated in its more basic form, monetary consideration. While fulfilling a mission is the reason for building a satellite, financial sponsors want a cost-effective system that does not either bankrupt the company or encompass 50% of the defense budget. All other design considerations discussed in the thesis such as physical limitations, reliability and performance, are directly affected by the two key design considerations. These important considerations ask the question: What is the system supposed to do, and how much is to be spent building it? It could be said that mission requirements start the project moving and monetary considerations impede that progress.

The design considerations discussed in the thesis are valid regardless of the size of the project. Granted, designing a satellite system such as MILSTAR is infinitely more complex than the relatively simple PANSAT, however, the same types of questions arise and the same pattern of evolution of ideas is followed in both instances.

The second portion of this study addressed the satellite licensing process. It was determined that three options existed in which PANSAT could obtain an operating frequency. These options were to categorize PANSAT as either an amateur, military or experimental satellite. The option being pursued by NPS is the amateur satellite classification. Advantages of the amateur option include the availability of the desired 435-438 MHz frequency band, the relatively simple application process, and the limited number of operational restrictions. The main disadvantage is that as an amateur satellite, PANSAT must be made available to all authorized amateur users and cannot be restricted to NPS usage. The amateur service also stresses formal operator qualifications more than the other two available options.

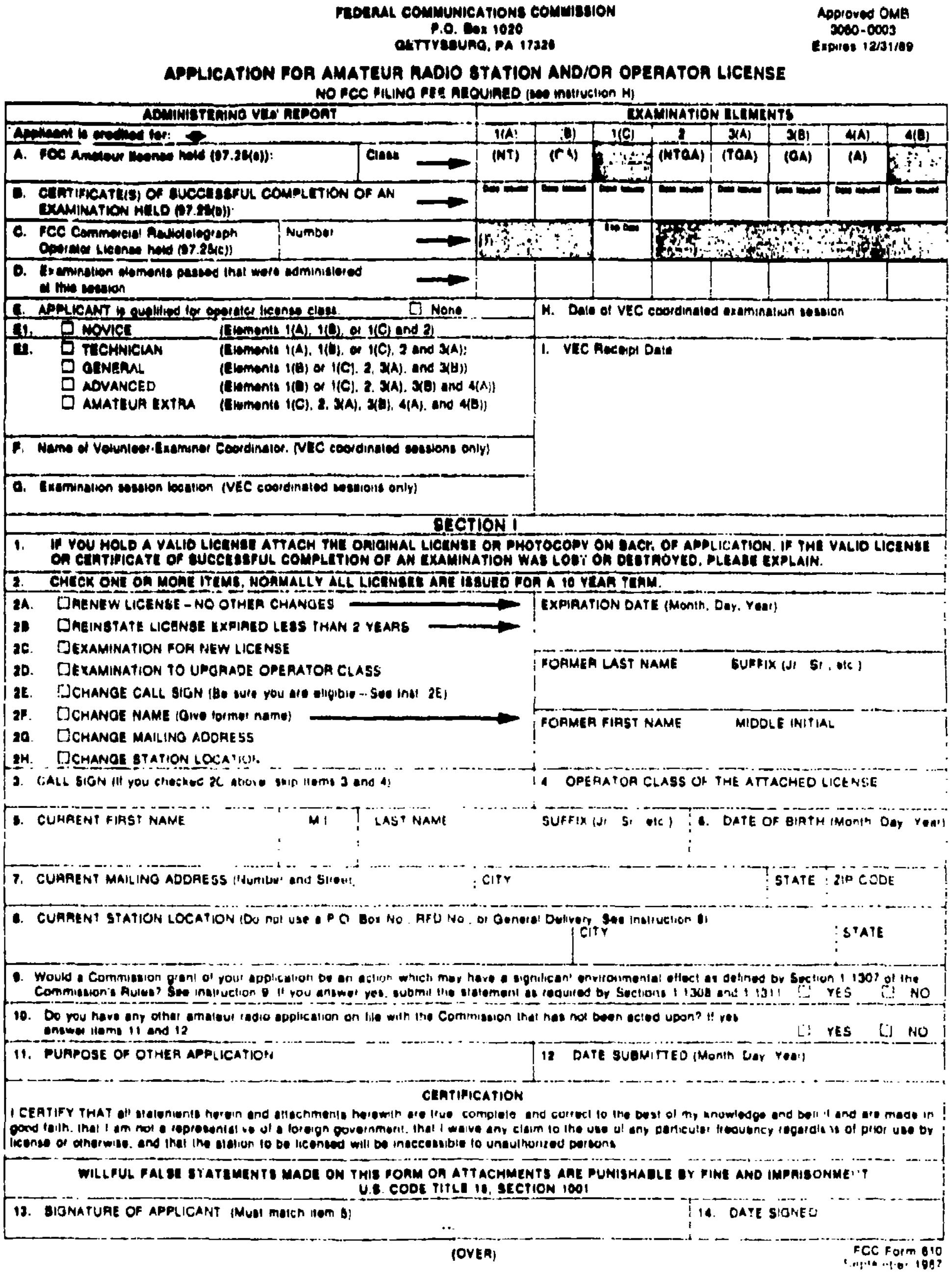
The military satellite classification was the first option examined. It was in fact NAVEMSCEN who first suggested that NPS pursue the amateur option. The advantages of this option are that PANSAT could be used as a dedicated NPS satellite, not available to the general public, and that operator qualifications are not stressed. Disadvantages include a very crowded UHF frequency band, the very complex and drawn out two stage frequency application process, the need to conduct an EMC study, and the massive coordination required to actually use the frequency after it has been assigned. This type of satellite frequency assignment process is designed more for major DOD projects such as FLTSATCOM or MILSTAR, in which hundreds of millions of dollars are expended and the project takes 10 to 15 years to design and build anyway. The process is not really conducive to a university's small inexpensive experimental satellite whose intent is to provide actual space operational experience to space system students. Should this method be pursued, it would be best to classify the satellite as a military experimental satellite in order to reduce frequency application processing time.

An experimental satellite classification would be the option of choice for PANSAT if NPS were a civilian university. Being a military institution, however, it would be difficult, if not impossible, to convince the FCC to give PANSAT experimental status. The FCC would probably insist that the satellite should be classified as a military experimental satellite, as in the prior paragraph. Advantages of the experimental option include the availability of any frequency band (except the amateur band), the satellite as a dedicated NPS platform, an extremely simple frequency application process, and a two month response time to the application. Disadvantages include increased operational restrictions and a limited license duration.

Summarizing the license options, an experimental satellite classification is desirable, but probably not feasible. This leaves an amateur satellite classification for PANSAT as the option of choice. The military experimental classification is available, but not tailor fit for a satellite such as PANSAT.

The amateur option has been chosen, but there is still future work to perform. The first pre-space notice has already been sent to the FCC for filing with the IFRB. Future work on the licensing process include filing the second pre-space notification five months prior to the anticipated launch date. Once operational, an in-space notice should be filed. Finally upon system termination, a post-space notice is filed. Before drafting any of these notices, the current edition of the pertinent references should be consulted. Federal rules and requirements, especially in the amateur service, are rapidly changing. Two years from this date, there could be vast changes to the requirements involving this constantly evolving field.

APPENDIX A. SAMPLE FCC FORM 610



FEDERAL COMMUNICATIONS COMMISSION
P.O. Box 1020
GETTYSBURG, PA 17326

Approved OMB
3060-0003
Expires 12/31/89

APPLICATION FOR AMATEUR RADIO STATION AND/OR OPERATOR LICENSE
NO FCC FILING FEE REQUIRED (see instruction H)

ADMINISTERING VEs' REPORT		**EXAMINATION ELEMENTS**							
Applicant is credited for:		1(A)	1(B)	1(C)	2	3(A)	3(B)	4(A)	4(B)
A. FCC Amateur license held (97.25(a)):	Class →	(NT)	(CA)		(NTGA)	(TGA)	(GA)	(A)	
B. CERTIFICATE(S) OF SUCCESSFUL COMPLETION OF AN EXAMINATION HELD (97.25(b)):	→	Date issued	Date issued	Date issued	Date issued	Date issued	Date issued	Date issued	Date issued
C. FCC Commercial Radiotelegraph Operator License held (97.25(c))	Number →			Exp Date					
D. Examination elements passed that were administered at this session	→								

E. APPLICANT is qualified for operator license class. ☐ None

E1. ☐ **NOVICE** (Elements 1(A), 1(B), or 1(C) and 2)

E2. ☐ **TECHNICIAN** (Elements 1(A), 1(B), or 1(C), 2 and 3(A))
☐ **GENERAL** (Elements 1(B) or 1(C), 2, 3(A), and 3(B))
☐ **ADVANCED** (Elements 1(B) or 1(C), 2, 3(A), 3(B) and 4(A))
☐ **AMATEUR EXTRA** (Elements 1(C), 2, 3(A), 3(B), 4(A), and 4(B))

F. Name of Volunteer-Examiner Coordinator. (VEC coordinated sessions only)

G. Examination session location (VEC coordinated sessions only)

H. Date of VEC coordinated examination session

I. VEC Receipt Date

SECTION I

1. IF YOU HOLD A VALID LICENSE ATTACH THE ORIGINAL LICENSE OR PHOTOCOPY ON BACK OF APPLICATION. IF THE VALID LICENSE OR CERTIFICATE OF SUCCESSFUL COMPLETION OF AN EXAMINATION WAS LOST OR DESTROYED, PLEASE EXPLAIN.

2. CHECK ONE OR MORE ITEMS, NORMALLY ALL LICENSES ARE ISSUED FOR A 10 YEAR TERM.

2A. ☐ RENEW LICENSE – NO OTHER CHANGES →
2B ☐ REINSTATE LICENSE EXPIRED LESS THAN 2 YEARS →
2C. ☐ EXAMINATION FOR NEW LICENSE
2D. ☐ EXAMINATION TO UPGRADE OPERATOR CLASS
2E. ☐ CHANGE CALL SIGN (Be sure you are eligible – See Inst 2E)
2F. ☐ CHANGE NAME (Give former name) →
2G. ☐ CHANGE MAILING ADDRESS
2H. ☐ CHANGE STATION LOCATION

EXPIRATION DATE (Month, Day, Year)

FORMER LAST NAME SUFFIX (Jr, Sr, etc.)

FORMER FIRST NAME MIDDLE INITIAL

3. CALL SIGN (If you checked 2C above skip items 3 and 4)

4 OPERATOR CLASS OF THE ATTACHED LICENSE

5. CURRENT FIRST NAME M.I. LAST NAME SUFFIX (Jr, Sr, etc.)

6. DATE OF BIRTH (Month Day Year)

7. CURRENT MAILING ADDRESS (Number and Street) CITY STATE ZIP CODE

8. CURRENT STATION LOCATION (Do not use a P.O. Box No., RFD No., or General Delivery. See instruction 8) CITY STATE

9. Would a Commission grant of your application be an action which may have a significant environmental effect as defined by Section 1.1307 of the Commission's Rules? See instruction 9. If you answer yes, submit the statement as required by Sections 1.1308 and 1.1311 ☐ YES ☐ NO

10. Do you have any other amateur radio application on file with the Commission that has not been acted upon? If yes answer items 11 and 12 ☐ YES ☐ NO

11. PURPOSE OF OTHER APPLICATION

12 DATE SUBMITTED (Month Day Year)

CERTIFICATION

I CERTIFY THAT all statements herein and attachments herewith are true, complete, and correct to the best of my knowledge and belief and are made in good faith, that I am not a representative of a foreign government, that I waive any claim to the use of any particular frequency regardless of prior use by license or otherwise, and that the station to be licensed will be inaccessible to unauthorized persons.

WILLFUL FALSE STATEMENTS MADE ON THIS FORM OR ATTACHMENTS ARE PUNISHABLE BY FINE AND IMPRISONMENT
U.S. CODE TITLE 18, SECTION 1001

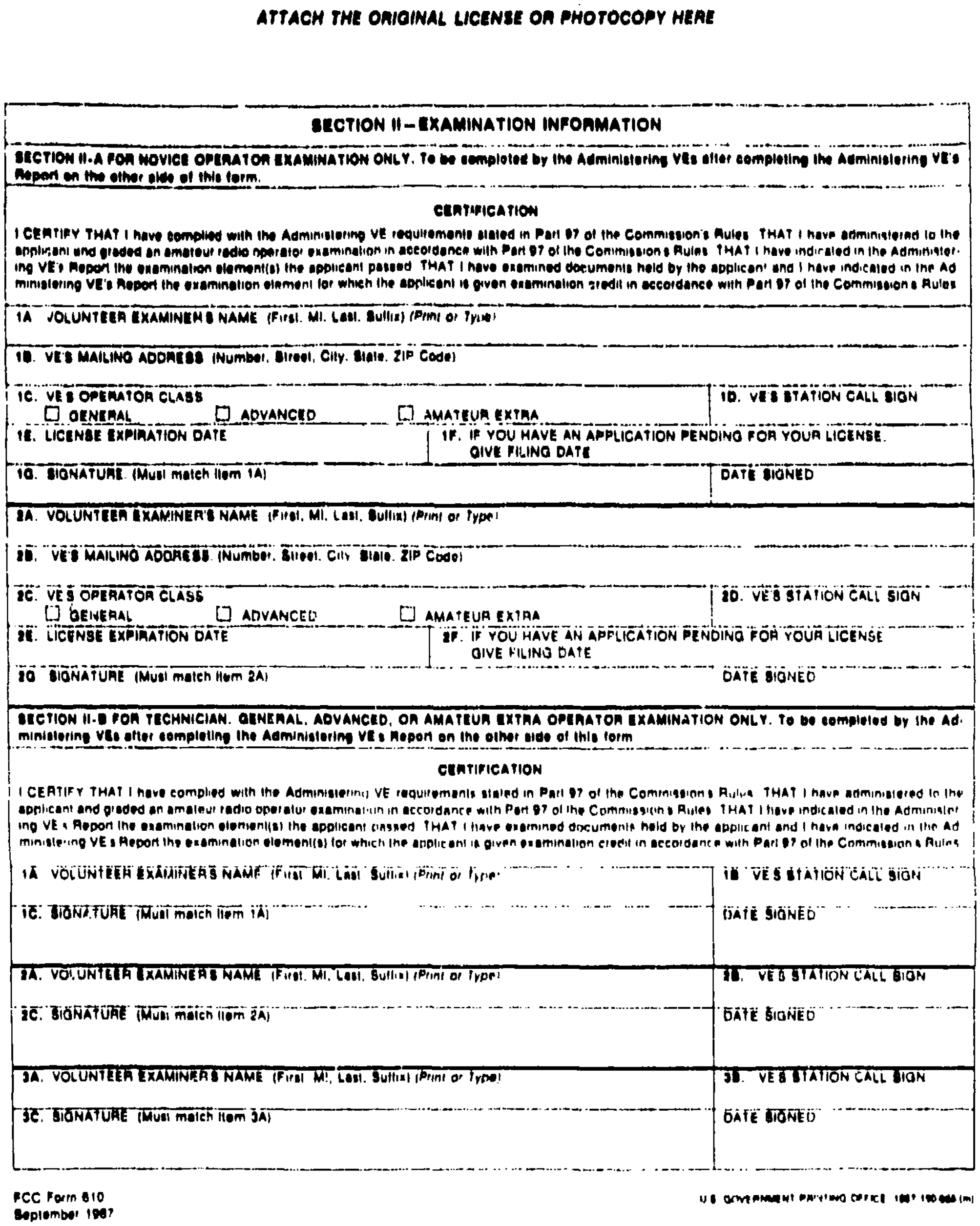
13. SIGNATURE OF APPLICANT (Must match item 5)

14. DATE SIGNED

(OVER)

FCC Form 610
September 1987

FCC form 610 (continued)



ATTACH THE ORIGINAL LICENSE OR PHOTOCOPY HERE

SECTION II – EXAMINATION INFORMATION

SECTION II-A FOR NOVICE OPERATOR EXAMINATION ONLY. To be completed by the Administering VEs after completing the Administering VE's Report on the other side of this form.

CERTIFICATION

I CERTIFY THAT I have complied with the Administering VE requirements stated in Part 97 of the Commission's Rules. THAT I have administered to the applicant and graded an amateur radio operator examination in accordance with Part 97 of the Commission's Rules. THAT I have indicated in the Administering VE's Report the examination element(s) the applicant passed. THAT I have examined documents held by the applicant and I have indicated in the Administering VE's Report the examination element for which the applicant is given examination credit in accordance with Part 97 of the Commission's Rules.

1A. VOLUNTEER EXAMINER'S NAME (First, MI, Last, Suffix) *(Print or Type)*

1B. VE'S MAILING ADDRESS (Number, Street, City, State, ZIP Code)

1C. VE'S OPERATOR CLASS ☐ GENERAL ☐ ADVANCED ☐ AMATEUR EXTRA

1D. VE'S STATION CALL SIGN

1E. LICENSE EXPIRATION DATE

1F. IF YOU HAVE AN APPLICATION PENDING FOR YOUR LICENSE, GIVE FILING DATE

1G. SIGNATURE (Must match Item 1A)

DATE SIGNED

2A. VOLUNTEER EXAMINER'S NAME (First, MI, Last, Suffix) *(Print or Type)*

2B. VE'S MAILING ADDRESS (Number, Street, City, State, ZIP Code)

2C. VE'S OPERATOR CLASS ☐ GENERAL ☐ ADVANCED ☐ AMATEUR EXTRA

2D. VE'S STATION CALL SIGN

2E. LICENSE EXPIRATION DATE

2F. IF YOU HAVE AN APPLICATION PENDING FOR YOUR LICENSE, GIVE FILING DATE

2G. SIGNATURE (Must match Item 2A)

DATE SIGNED

SECTION II-B FOR TECHNICIAN, GENERAL, ADVANCED, OR AMATEUR EXTRA OPERATOR EXAMINATION ONLY. To be completed by the Administering VEs after completing the Administering VE's Report on the other side of this form.

CERTIFICATION

I CERTIFY THAT I have complied with the Administering VE requirements stated in Part 97 of the Commission's Rules. THAT I have administered to the applicant and graded an amateur radio operator examination in accordance with Part 97 of the Commission's Rules. THAT I have indicated in the Administering VE's Report the examination element(s) the applicant passed. THAT I have examined documents held by the applicant and I have indicated in the Administering VE's Report the examination element(s) for which the applicant is given examination credit in accordance with Part 97 of the Commission's Rules.

1A. VOLUNTEER EXAMINER'S NAME (First, MI, Last, Suffix) *(Print or Type)*

1B. VE'S STATION CALL SIGN

1C. SIGNATURE (Must match Item 1A)

DATE SIGNED

2A. VOLUNTEER EXAMINER'S NAME (First, MI, Last, Suffix) *(Print or Type)*

2B. VE'S STATION CALL SIGN

2C. SIGNATURE (Must match Item 2A)

DATE SIGNED

3A. VOLUNTEER EXAMINER'S NAME (First, MI, Last, Suffix) *(Print or Type)*

3B. VE'S STATION CALL SIGN

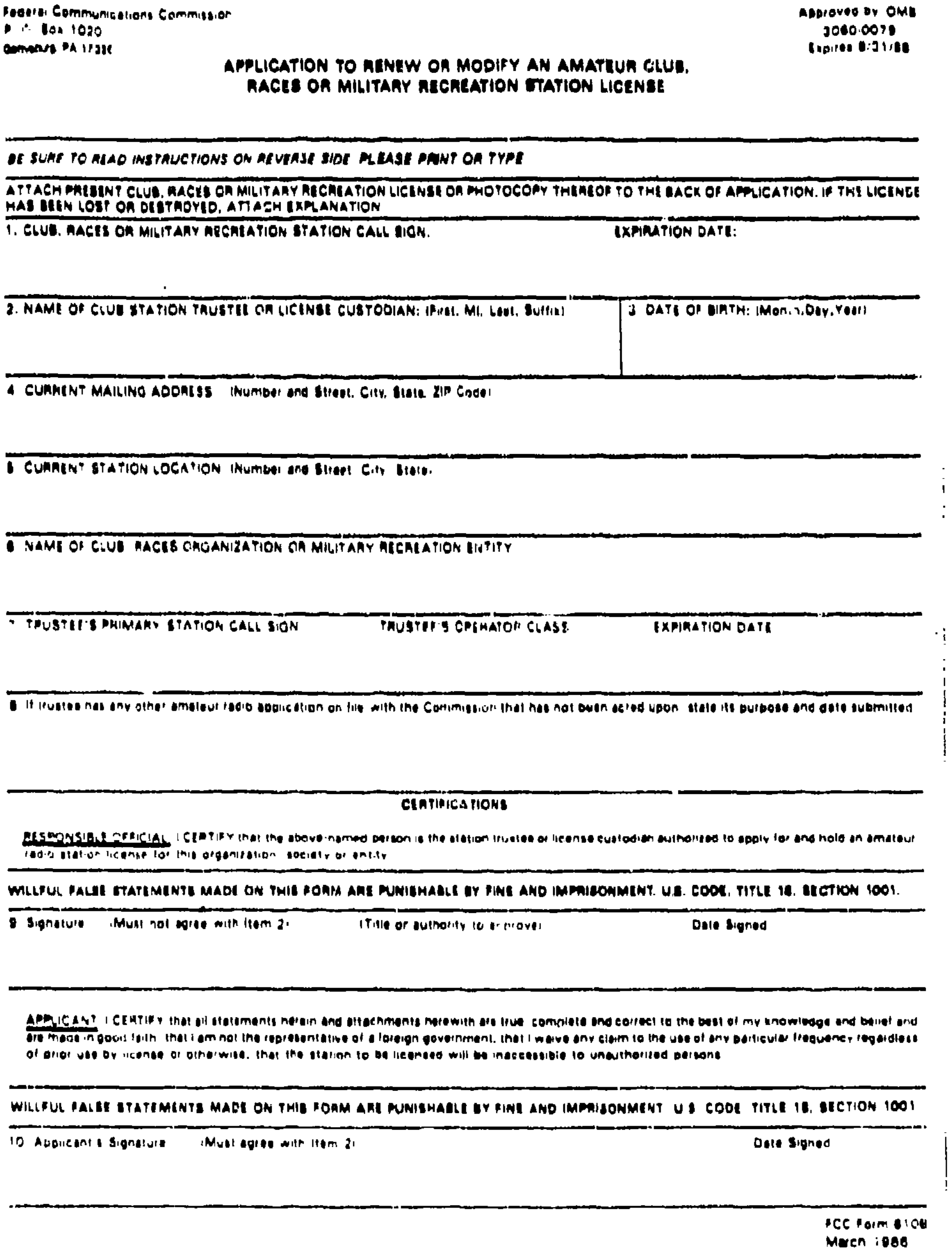
3C. SIGNATURE (Must match Item 3A)

DATE SIGNED

FCC Form 610
September 1987

U.S. GOVERNMENT PRINTING OFFICE 1987 190-666 (m)

APPENDIX B. SAMPLE FCC FORM 610B



Federal Communications Commission
P. O. Box 1020
Gettysburg PA 17326

Approved by OMB
3060-0079
Expires 8/31/88

APPLICATION TO RENEW OR MODIFY AN AMATEUR CLUB, RACES OR MILITARY RECREATION STATION LICENSE

BE SURE TO READ INSTRUCTIONS ON REVERSE SIDE PLEASE PRINT OR TYPE

ATTACH PRESENT CLUB, RACES OR MILITARY RECREATION LICENSE OR PHOTOCOPY THEREOF TO THE BACK OF APPLICATION. IF THE LICENSE HAS BEEN LOST OR DESTROYED, ATTACH EXPLANATION

1. CLUB, RACES OR MILITARY RECREATION STATION CALL SIGN. EXPIRATION DATE:

2. NAME OF CLUB STATION TRUSTEE OR LICENSE CUSTODIAN: (First, MI, Last, Suffix)

3. DATE OF BIRTH: (Month,Day,Year)

4. CURRENT MAILING ADDRESS (Number and Street, City, State, ZIP Code)

5. CURRENT STATION LOCATION (Number and Street, City, State)

6. NAME OF CLUB, RACES ORGANIZATION OR MILITARY RECREATION ENTITY

7. TRUSTEE'S PRIMARY STATION CALL SIGN TRUSTEE'S OPERATOR CLASS EXPIRATION DATE

8. If trustee has any other amateur radio application on file with the Commission that has not been acted upon, state its purpose and date submitted

CERTIFICATIONS

RESPONSIBLE OFFICIAL: I CERTIFY that the above-named person is the station trustee or license custodian authorized to apply for and hold an amateur radio station license for this organization, society or entity.

WILLFUL FALSE STATEMENTS MADE ON THIS FORM ARE PUNISHABLE BY FINE AND IMPRISONMENT. U.S. CODE, TITLE 18, SECTION 1001.

9. Signature (Must not agree with Item 2) (Title or authority to approve) Date Signed

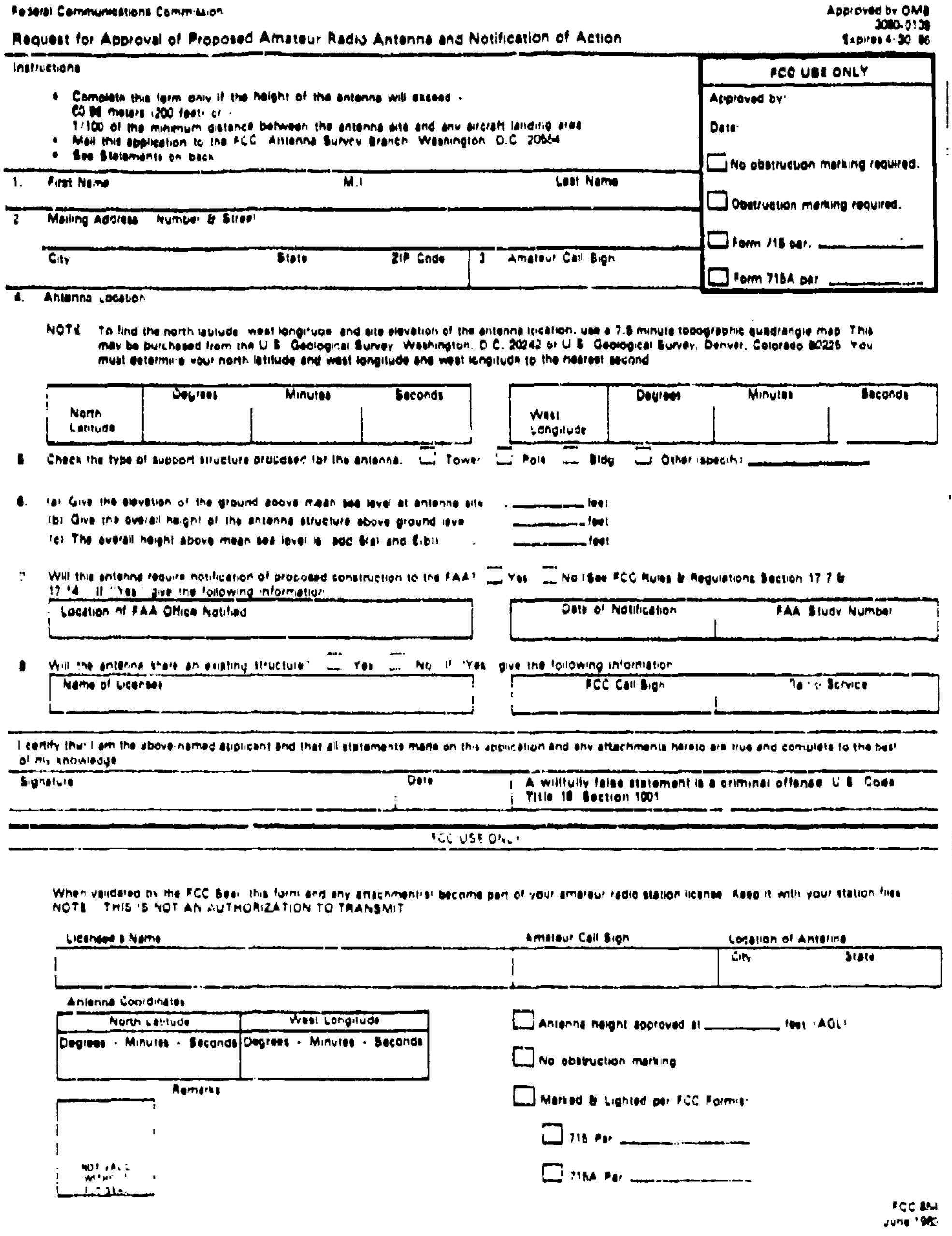
APPLICANT: I CERTIFY that all statements herein and attachments herewith are true, complete and correct to the best of my knowledge and belief and are made in good faith; that I am not the representative of a foreign government; that I waive any claim to the use of any particular frequency regardless of prior use by license or otherwise; that the station to be licensed will be inaccessible to unauthorized persons

WILLFUL FALSE STATEMENTS MADE ON THIS FORM ARE PUNISHABLE BY FINE AND IMPRISONMENT. U.S. CODE, TITLE 18, SECTION 1001

10. Applicant's Signature (Must agree with Item 2) Date Signed

FCC Form 610B
March 1986

APPENDIX C. SAMPLE FCC FORM 854



Federal Communications Commission

Approved by OMB
3060-0139
Expires 4-30-86

Request for Approval of Proposed Amateur Radio Antenna and Notification of Action

Instructions

- Complete this form only if the height of the antenna will exceed -
  60.96 meters (200 feet) or -
  1/100 of the minimum distance between the antenna site and any aircraft landing area
- Mail this application to the FCC, Antenna Survey Branch, Washington, D.C. 20554
- See Statements on back

FCC USE ONLY

Approved by:

Date:

☐ No obstruction marking required.

☐ Obstruction marking required.

☐ Form 715 par. ____________

☐ Form 715A par. ____________

1. First Name M.I. Last Name

2. Mailing Address Number & Street

City State ZIP Code

3. Amateur Call Sign

4. Antenna Location

NOTE To find the north latitude, west longitude, and site elevation of the antenna location, use a 7.5 minute topographic quadrangle map. This may be purchased from the U.S. Geological Survey, Washington, D.C. 20242 or U.S. Geological Survey, Denver, Colorado 80225. You must determine your north latitude and west longitude and west longitude to the nearest second.

	Degrees	Minutes	Seconds
North Latitude			

	Degrees	Minutes	Seconds
West Longitude			

5. Check the type of support structure proposed for the antenna. ☐ Tower ☐ Pole ☐ Bldg ☐ Other (specify) ____________

6. (a) Give the elevation of the ground above mean sea level at antenna site ____________ feet
   (b) Give the overall height of the antenna structure above ground level ____________ feet
   (c) The overall height above mean sea level is (add 6(a) and 6(b)) ____________ feet

7. Will this antenna require notification of proposed construction to the FAA? ☐ Yes ☐ No (See FCC Rules & Regulations Section 17.7 & 17.14) If "Yes" give the following information

Location of FAA Office Notified	Date of Notification	FAA Study Number

8. Will the antenna share an existing structure? ☐ Yes ☐ No If "Yes" give the following information

Name of Licensee	FCC Call Sign	Radio Service

I certify that I am the above-named applicant and that all statements made on this application and any attachments hereto are true and complete to the best of my knowledge.

Signature Date

A willfully false statement is a criminal offense. U.S. Code Title 18, Section 1001

FCC USE ONLY

When validated by the FCC Seal, this form and any attachment(s) become part of your amateur radio station license. Keep it with your station files.
NOTE THIS IS NOT AN AUTHORIZATION TO TRANSMIT

Licensee's Name	Amateur Call Sign	Location of Antenna City State

Antenna Coordinates

North Latitude	West Longitude
Degrees - Minutes - Seconds	Degrees - Minutes - Seconds

Remarks

NOT VALID WITHOUT FCC SEAL

☐ Antenna height approved at ____________ feet (AGL)

☐ No obstruction marking

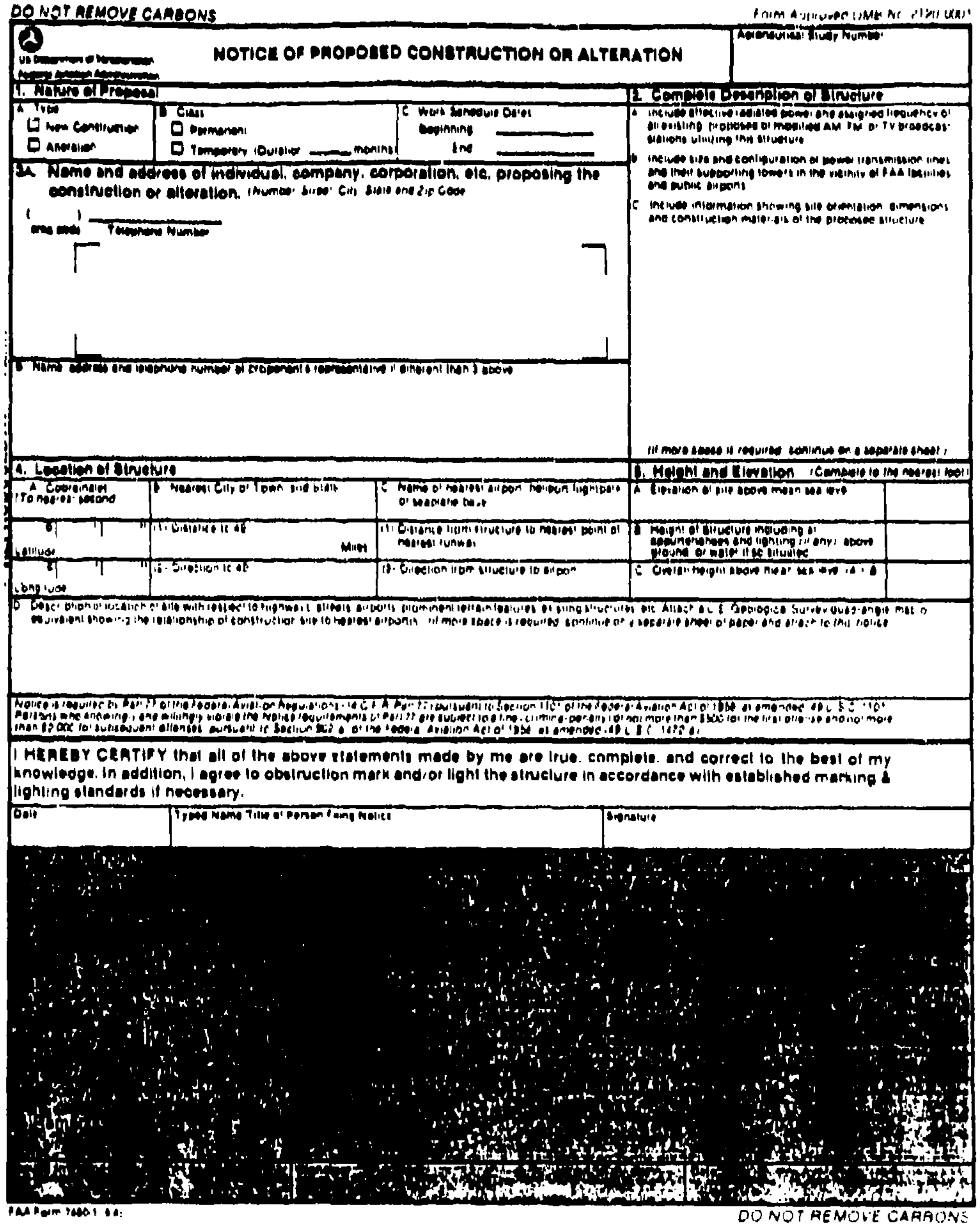
☐ Marked & Lighted per FCC Forms:

☐ 715 Par ____________

☐ 715A Par ____________

FCC 854
June 19[illegible]

APPENDIX D. SAMPLE FAA FORM 7460-1



DO NOT REMOVE CARBONS

Form Approved OMB No. 2120-0001

US Department of Transportation
Federal Aviation Administration

NOTICE OF PROPOSED CONSTRUCTION OR ALTERATION

Aeronautical Study Number

1. Nature of Proposal

A. Type
☐ New Construction
☐ Alteration

B. Class
☐ Permanent
☐ Temporary (Duration ____ months)

C. Work Schedule Dates
Beginning ____
End ____

2. Complete Description of Structure

A. Include effective radiated power and assigned frequency of all existing, proposed or modified AM, FM, or TV broadcast stations utilizing this structure.

B. Include size and configuration of power transmission lines and their supporting towers in the vicinity of FAA facilities and public airports.

C. Include information showing site orientation, dimensions, and construction materials of the proposed structure.

(If more space is required, continue on a separate sheet.)

3A. Name and address of individual, company, corporation, etc. proposing the construction or alteration. (Number, Street, City, State and Zip Code)

( ) ____
area code Telephone Number

B. Name, address and telephone number of proponent's representative if different than 3 above

4. Location of Structure

A. Coordinates (To nearest second)	B. Nearest City or Town, and State	C. Name of nearest airport, heliport, flightpark, or seaplane base
° ' " Latitude	(1) Distance to 4B Miles	(1) Distance from structure to nearest point of nearest runway
° ' " Longitude	(2) Direction to 4B	(2) Direction from structure to airport

D. Description of location of site with respect to highways, streets, airports, prominent terrain features, existing structures, etc. Attach a U.S. Geological Survey quadrangle map or equivalent showing the relationship of construction site to nearest airports. (If more space is required, continue on a separate sheet of paper and attach to this notice.)

5. Height and Elevation (Complete to the nearest foot)

A. Elevation of site above mean sea level	
B. Height of structure including all appurtenances and lighting (if any) above ground, or water if so situated	
C. Overall height above mean sea level (A + B)	

Notice is required by Part 77 of the Federal Aviation Regulations (14 C.F.R. Part 77) pursuant to Section 1101 of the Federal Aviation Act of 1958, as amended (49 U.S.C. 1101). Persons who knowingly and willingly violate the Notice requirements of Part 77 are subject to a fine (criminal penalty) of not more than $500 for the first offense and not more than $2,000 for subsequent offenses, pursuant to Section 902(a) of the Federal Aviation Act of 1958, as amended (49 U.S.C. 1472(a)).

I HEREBY CERTIFY that all of the above statements made by me are true, complete, and correct to the best of my knowledge. In addition, I agree to obstruction mark and/or light the structure in accordance with established marking & lighting standards if necessary.

Date	Typed Name/Title of Person Filing Notice	Signature

FAA Form 7460-1 [illegible]

DO NOT REMOVE CARBONS

APPENDIX E. PANSAT'S FIRST PRE-SPACE NOTIFICATION

A. SAMPLE COVER SHEET

Naval Postgraduate School
Space Systems Academic Group
Code SP(72)
Monterey, Ca. 93943

1 May 1990

Federal Communications Commission
Personal Radio Branch
Rm 5322
1919 M St. Northwest
Washington, DC 20554
ATTN: Mr. John Johnston

Dear Mr. Johnston,

The Naval Postgraduate School's (NPS) Space Systems Academic Group has designed and is presently constructing a small amateur communications satellite. NPS's Petite Amateur Navy Satellite (PANSAT) will provide the amateur community the opportunity to work with a spread spectrum communications capability as well as acting as an on-orbit laboratory for Space Systems students at NPS. PANSAT will also carry two experimental payloads. The first will test the performance of solar cells and their degradation. PANSAT's second experimental payload will involve testing the relatively new technology of ferroelectric memory. Both experiments could produce valuable data which could affect the development of future space related hardware. NPS has been in contact with the Radio Amateur Satellite Corporation (AMSAT) while developing the communications package on PANSAT.

At this time, NPS wishes to request that the Commission authorize the operation of PANSAT into the Amateur Satellite Service. It is anticipated that PANSAT will be launched around 30 July 1992. The licensee trustee for this satellite is Mr. Max Cornell/K0MC, who holds a valid amateur extra class license, and will be directly involved with the command and control operations of the satellite prior to and after launch.

The licensee/trustee's name, license address, and station address are as follows:

Address of Operator's License:

Max A. Cornell/K0MC
Code 62EL NPS
Monterey, Ca. 93943

Address of Station License:

K6LY
BLDG 205 NPS
Monterey, Ca. 93943

In accordance with Part 97.423 of the Commission's rules, NPS is providing IFRB Advance Publication Information in the format of Appendix 4 of the ITU Radio Regulations. This information follows this cover letter. This correspondence is intended to be the first pre-space operation notification. The second pre-space operation notification will be filed in January 1992. It would be much appreciated if the Commission would file the first notice with the IFRB on our behalf.

It is requested that you advise NPS when the notification is being forwarded to the IFRB of the International Telecommunications Union. Your attention to this matter is greatly appreciated. If there are any questions regarding this matter, please feel free to contact me, XXXXXX XXXXXX, or Daniel Sakoda at NPS Code SP(72), Monterey, Ca. 93943. The phone number is (408) 646-2299.

Sincerely,

XXXXXX X XXXXXX
PANSAT design team

B. INFORMATION FOR ADVANCE PUBLICATION OF PANSAT AMATEUR RADIO SATELLITE

Section A: General Information

The administration of the United States of America informs the members of the ITU of its intention to authorize the operation of a satellite into the Amateur Satellite Service. The Petite Amateur Navy Satellite (PANSAT) will operate in low earth orbit and provide licensed radio amateurs with the opportunity to work with a spread spectrum communications capability. The satellite will be licensed by the administration of the United States of America and is the subject of this Advanced Publication Information.

Section B: General Characteristics to be Furnished for Satellite

1. Identification of Satellite:

PANSAT-OSCAR-(TBD)

2. Date of Initial Operation:

30 July 1992

3. Administration Submitting Advance Information:

United States of America
Federal Communications Commission
Washington, DC 20554

4. Orbital Information Relating to the Satellite:

Inclination: 28.4 deg
Period: 94 min
Apogee: 480 km
Perigee: 480 km

Number of satellites with the same characteristics: 1

Section C: Characteristics of Satellite System in Earth-to-Space Direction

1. Earth-to-Space Service Area:

United States

2. Classes of Stations and Nature of Service:

EA, TA, TD, TR, OT, HX, I, ND

3. Frequency Range:

Centered on 437.25 MHz for both telecommand and user stations

4. Power Characteristics into the Transmit Antenna:

Maximum Spectral Power Density:

Telecommand: -53 dBw/Hz
User Earth Stations: -50 dBW/Hz

Typical Antenna Radiation Pattern:

Telecommand...............Beamwidth: Omnidirectional
Polarization: Circular, RHC or LHC
Amateur Satellite User....Beamwidth: Omnidirectional
Polarization: Circular, RHC or LHC

5. Characteristics of Space Station Receiving Antenna:

Gain: +0 dBi, omnidirectional
Polarization: Linear

6. Noise Temperature of Space Station Receiver:

1000 K

7. Necessary Bandwidth:

Telecommand and User Channels: 1200 Hz spread out to 1 MHz

8. Modulation Characteristics:

BPSK direct sequence spread spectrum

Section D: Characteristics of Satellite System in Space-to-Earth Direction

1. Space-to-Earth Service Area:

United States

2. Classes of Stations and Nature of Service:

EA, TA, TD, TR, OT, HX, I, ND

3. Frequency Range:

Centered on 437.25 MHz for both telecommand and user stations

4. Power Characteristics of Transmission into Antenna:

Maximum Power Spectral Density: -53 dBW/Hz
Minimum Carrier Power: 5 W (7 dBW)

5. Characteristics of Space Station Transmitting Antenna:

Gain: + 3.0 dBiC, Omnidirectional
Polarization: RHC or LHC (Apparent polarization varies with spacecraft rotation)

6. Characteristics of Typical Receiving Earth Station:

Total Receiving Noise Temperature: 400 K

Typical Receiving Antenna Radiation Pattern:

Gain: +0 dBi

Pattern: omnidirectional in azimuth

Polarization: linear, vertical

Figure of Merit (G/T): -26 dB/K

7. Necessary Bandwidth:

1200 Hz spread out to 1 MHz

8. Modulation Characteristics:

BPSK direct sequence spread spectrum

Section E: Characteristics of Space-to-Space Relays

Not Applicable

Section F: Supplementary Information

None

APPENDIX F. PANSAT'S SECOND PRE-SPACE NOTIFICATION

A. SAMPLE COVER LETTER

Naval Postgraduate School
Space Systems Academic Group
Code SP(72)
Monterey, Ca. 93943

1 February 1992

Federal Communications Commission
Personal Radio Branch
Rm 5322
1919 M Street NW
Washington, D.C. 20554
Attn: Mr. John Johnston

Dear Mr. Johnston,

This letter is a follow up on the correspondence sent to you from this organization dated 1 May 1990. The prior correspondence was the first pre-space notification for Petite Amateur Navy Satellite (PANSAT). We thank you and the Commission for filing the first notice with the IFRB on our behalf.

The anticipated launch date of 31 July 1992 is still valid. There has been a change in the satellite sponsor/trustee. The new trustee for PANSAT is to be R.W. Adler, who holds a valid amateur extra class license, and will be directly involved with the command and control operations of the satellite prior to and after launch. The licensee/trustee's name, license address, and station address are as follows:

Address of Operator's License:

R.W. Adler KKKK
BLDG 205 NPS
Monterey, Ca. 93943

Address of Station License:

K6LY
BLDG 205 NPS
Monterey, Ca. 93943

In accordance with Part 97.423 of the Commission's rules, NPS is providing IFRB Advance Publication Information in the format of Appendix 3 if the ITU Radio Regulations. This information follows this cover letter. This correspondence is intended to be the second pre-space operation notification. The in-space notification will be filed within seven days of launch, per the FCC rules. It would be much appreciated if the Commission would file this second notice with the IFRB on our behalf.

We thank you for your attention to this matter. Should any questions arise, please contact Daniel Sakoda at NPS Code SP(72), Monterey, Ca. 93943. The phone number is (408) 646-2299.

Sincerely,

XXXXX X XXXXX
PANSAT design team

B. INFORMATION FOR SECOND NOTICE OF ADVANCE PUBLICATION OF PANSAT

Section A: General Information

The administration of the United States of America informs the members of the ITU of its intention to authorize the operation of a satellite into the Amateur Satellite Service. The Petite Amateur Navy Satellite (PANSAT) will operate in low earth orbit and provide licensed amateurs the opportunity to work with a spread spectrum communications capability. This will be the first use of the assigned frequency by this station. This is the second pre-space notification. The first advance notification was published in the ITU's weekly circular of XX Month 199X. The satellite will be licensed by the administration of the United States of America, and is the subject of this Advanced Publication Information.

Section B: Basic Characteristics to Be Furnished in Notices Relating to Frequencies Used by Earth Stations for Transmitting

1. *Assigned Frequency:*

   437.25 MHz

2. *Assigned Frequency Band:*

   436.75-437.75 MHz

3. *Date of Bringing into Use:*

   31 July 1992

4. *Identity and Location of the Transmitting Earth Station:*

Naval Postgraduate School, Monterey, California, U.S.A.
36.35 N 121.55 W

5. *Station with which Communication Is to Be Established:*

PANSAT-OSCAR-(TBD)

6. *Class of Station and Nature of Service:*

EA, TA, TD, TR, OT, HX, I, ND

7. *Class of Emission, Necessary Bandwidth and Description of Transmission:*

Spread Spectrum
437.25 MHz center frequency
1.2 kHz bandwidth spread out to 960 kHz

8. *Power Characteristics of the Transmission:*

0 dbW input to the antenna
-50 dBW/Hz power density

9. *Transmitting Antenna Characteristics:*

(For a typical station)

Gain: 0 dB

Beamwidth: omnidirectional

Polarization: circular, RHC or LHC

Altitude: 90 m MSL

10. *Modulation Characteristics:*

BPSK direct sequence spread spectrum

11. *Regular Hours of Operation:*

1500-2400 UTC

12. *Coordination:*

United States of America

13. *Agreements:*

Not Applicable

14. *Operating Administration or Company:*

Federal Communications Commission

1919 M St. NW
Washington, D.C. 20554
phone: (202) 653-8144

Section C: Basic Characteristics to Be Furnished in Notices Relating to Frequencies to Be Received by Earth Stations

1. *Assigned Frequency:*

437.25 MHz

2. *Assigned Frequency Band:*

436.75-437.75 MHz

3. *Date of Bringing into Use:*

31 July 1992

4. *Identity and Location of the Receiving Earth Station:*

Naval Postgraduate School, Monterey, California, U.S.A.
36.35 N 121.55 W

5. *Station with which Communication Is to Be Established:*

PANSAT-OSCAR-(TBD)

6. *Class of Station and Nature of Service:*

EA, TA, TD, TR, OT, HX, I, ND

7. *Class of Emission, Necessary Bandwidth and Description of the Transmission to Be Received:*

Spread Spectrum
437.25 center frequency
1.2 kHz bandwidth spread out to 960 kHz

8. *Earth Station Receiving Antenna Characteristics:*

(For a typical station)
Pattern: omnidirectional
Polarization: linear, vertical
Figure of Merit: -26 dB °K
Altitude: 90 m MSL

9. *Noise Temperature, Link Noise Temperature and Transmission Gain:*

400 °K, 290 °K and 0 dB, respectively

10. *Regular Hours of Operation:*

1500-2400 UTC

11. *Coordination:*

United States of America

12. *Agreements:*

Not Applicable

13. *Operating Administration or Company:*

Federal Communications Commission
1919 M St. NW
Washington, D.C. 20554

Section D: Basic Characteristics to Be Furnished in Notices Relating to Frequencies Used by Space Stations for Transmitting

1. *Assigned Frequency:*

437.25 MHz

2. *Assigned Frequency Band:*

436.75-437.75 MHz

3. *Date of Bringing into Use:*

31 July 1992

4. *Identity of the Space Station:*

PANSAT-OSCAR-(TBD)

5. *Orbital Information:*

Inclination: 28.5°

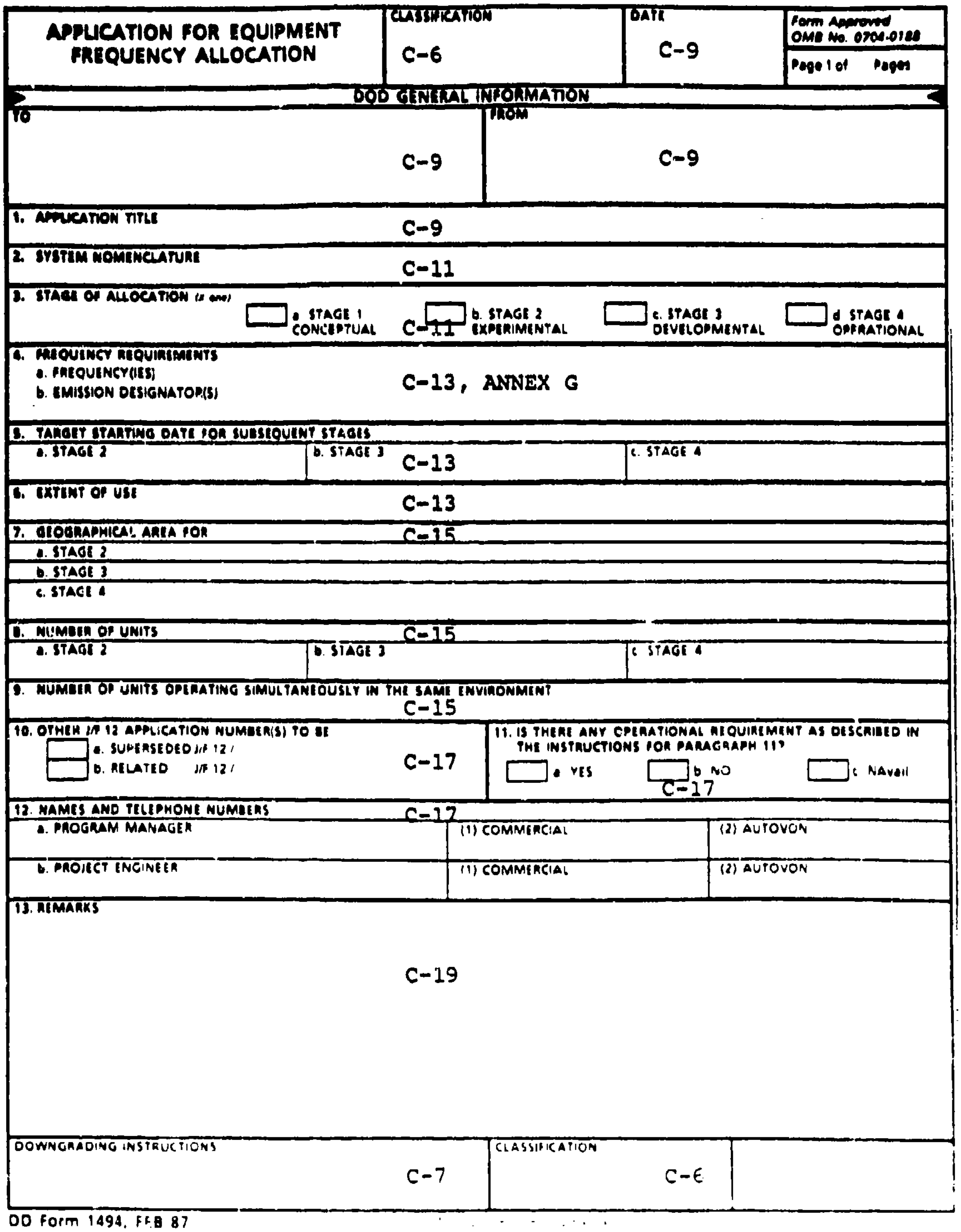
Period: 94 min

Apogee: 480 km

Perigee: 480 km

Number of Satellites in Constellation: 1

APPENDIX G. SAMPLE DD FORM 1494



APPLICATION FOR EQUIPMENT FREQUENCY ALLOCATION	CLASSIFICATION C-6	DATE C-9	Form Approved OMB No. 0704-0188 Page 1 of Pages

DOD GENERAL INFORMATION

TO C-9	FROM C-9

1. APPLICATION TITLE C-9

2. SYSTEM NOMENCLATURE C-11

3. STAGE OF ALLOCATION (x one) C-11
☐ a. STAGE 1 CONCEPTUAL ☐ b. STAGE 2 EXPERIMENTAL ☐ c. STAGE 3 DEVELOPMENTAL ☐ d. STAGE 4 OPERATIONAL

4. FREQUENCY REQUIREMENTS C-13, ANNEX G
a. FREQUENCY(IES)
b. EMISSION DESIGNATOR(S)

5. TARGET STARTING DATE FOR SUBSEQUENT STAGES C-13

a. STAGE 2	b. STAGE 3	c. STAGE 4

6. EXTENT OF USE C-13

7. GEOGRAPHICAL AREA FOR C-15
a. STAGE 2
b. STAGE 3
c. STAGE 4

8. NUMBER OF UNITS C-15

a. STAGE 2	b. STAGE 3	c. STAGE 4

9. NUMBER OF UNITS OPERATING SIMULTANEOUSLY IN THE SAME ENVIRONMENT C-15

10. OTHER J/F 12 APPLICATION NUMBER(S) TO BE ☐ a. SUPERSEDED J/F 12 / ☐ b. RELATED J/F 12 / C-17	11. IS THERE ANY OPERATIONAL REQUIREMENT AS DESCRIBED IN THE INSTRUCTIONS FOR PARAGRAPH 11? ☐ a YES ☐ b NO ☐ c NAvail C-17

12. NAMES AND TELEPHONE NUMBERS C-17

a. PROGRAM MANAGER	(1) COMMERCIAL	(2) AUTOVON
b. PROJECT ENGINEER	(1) COMMERCIAL	(2) AUTOVON

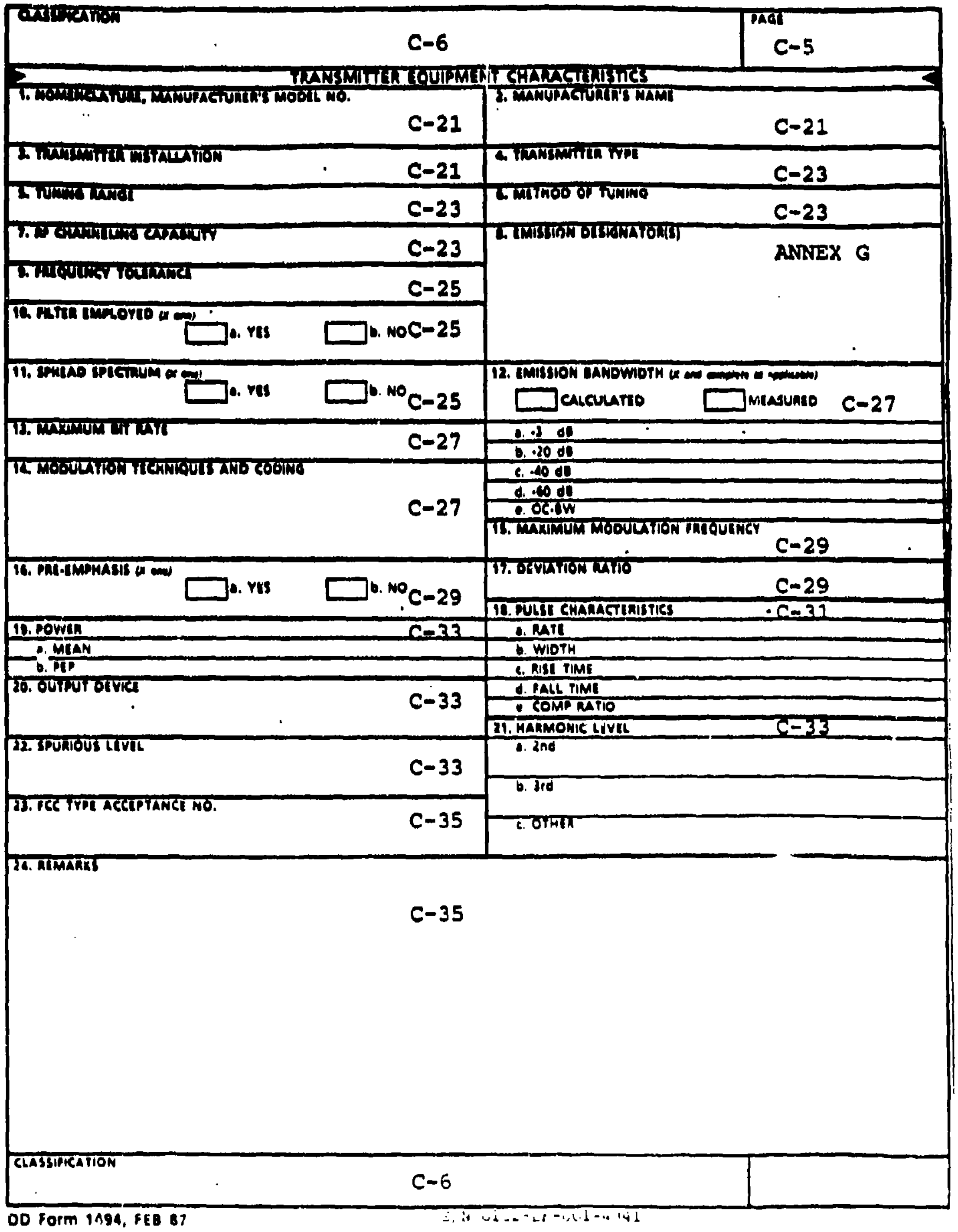
13. REMARKS

C-19

DOWNGRADING INSTRUCTIONS C-7	CLASSIFICATION C-6	

DD Form 1494, FEB 87

DD Form 1494 (continued)



CLASSIFICATION C-6

PAGE C-5

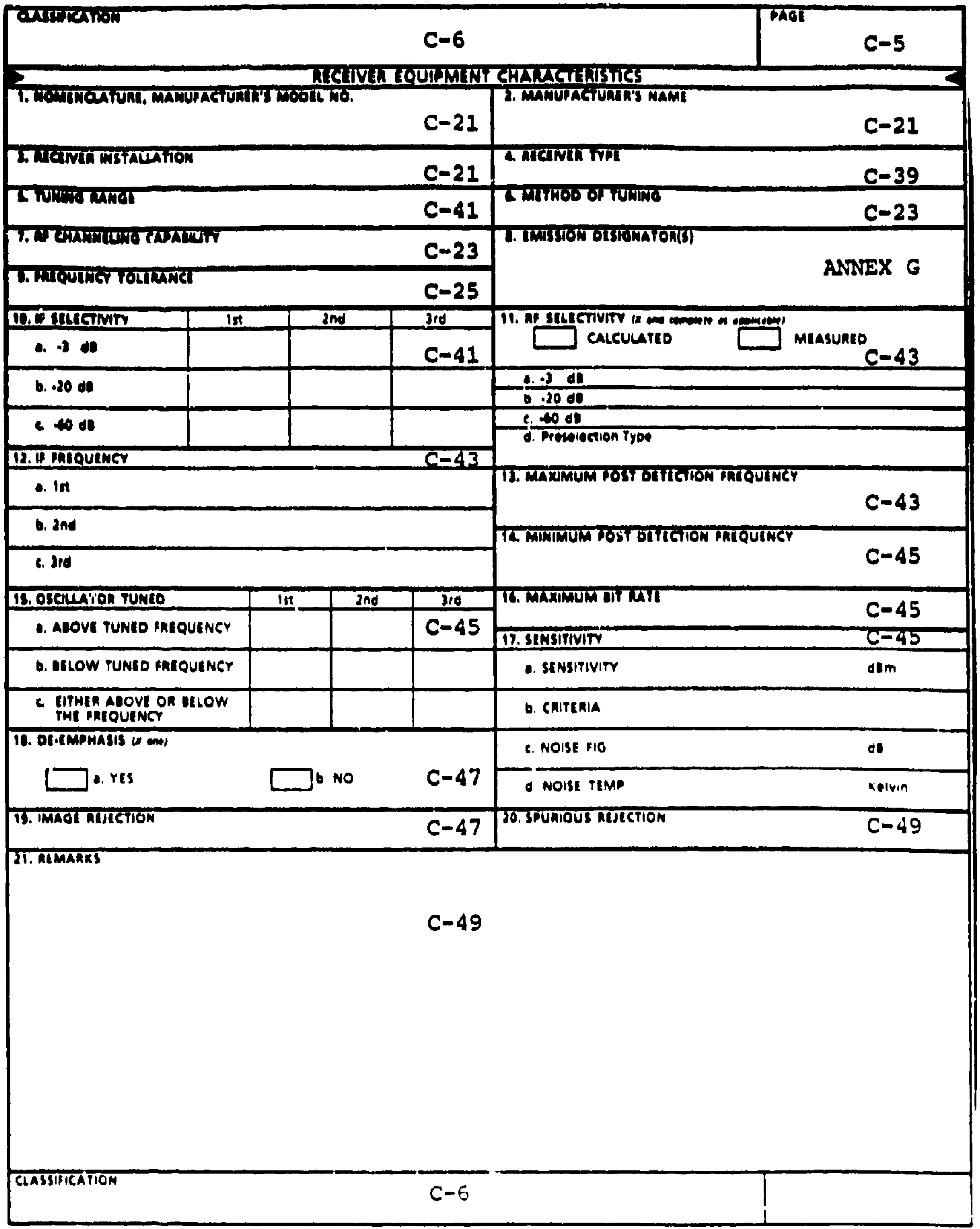
TRANSMITTER EQUIPMENT CHARACTERISTICS

1. NOMENCLATURE, MANUFACTURER'S MODEL NO. C-21
2. MANUFACTURER'S NAME C-21
3. TRANSMITTER INSTALLATION C-21
4. TRANSMITTER TYPE C-23
5. TUNING RANGE C-23
6. METHOD OF TUNING C-23
7. RF CHANNELING CAPABILITY C-23
8. EMISSION DESIGNATOR(S) ANNEX G
9. FREQUENCY TOLERANCE C-25
10. FILTER EMPLOYED (X one) ☐ a. YES ☐ b. NO C-25
11. SPREAD SPECTRUM (X one) ☐ a. YES ☐ b. NO C-25
12. EMISSION BANDWIDTH (X and complete as applicable) ☐ CALCULATED ☐ MEASURED C-27
    a. -3 dB
    b. -20 dB
    c. -40 dB
    d. -60 dB
    e. OC-BW
13. MAXIMUM BIT RATE C-27
14. MODULATION TECHNIQUES AND CODING C-27
15. MAXIMUM MODULATION FREQUENCY C-29
16. PRE-EMPHASIS (X one) ☐ a. YES ☐ b. NO C-29
17. DEVIATION RATIO C-29
18. PULSE CHARACTERISTICS C-31
    a. RATE
    b. WIDTH
    c. RISE TIME
    d. FALL TIME
    e. COMP RATIO
19. POWER C-33
    a. MEAN
    b. PEP
20. OUTPUT DEVICE C-33
21. HARMONIC LEVEL C-33
    a. 2nd
    b. 3rd
    c. OTHER
22. SPURIOUS LEVEL C-33
23. FCC TYPE ACCEPTANCE NO. C-35
24. REMARKS C-35

CLASSIFICATION C-6

DD Form 1494, FEB 87

DD Form 1494 (continued)



CLASSIFICATION C-6	PAGE C-5

RECEIVER EQUIPMENT CHARACTERISTICS

1. NOMENCLATURE, MANUFACTURER'S MODEL NO. C-21	2. MANUFACTURER'S NAME C-21
3. RECEIVER INSTALLATION C-21	4. RECEIVER TYPE C-39
5. TUNING RANGE C-41	6. METHOD OF TUNING C-23
7. RF CHANNELING CAPABILITY C-23	8. EMISSION DESIGNATOR(S) ANNEX G
9. FREQUENCY TOLERANCE C-25	

10. IF SELECTIVITY	1st	2nd	3rd
a. -3 dB			C-41
b. -20 dB			
c. -60 dB			

11. RF SELECTIVITY (X one complete as applicable)
☐ CALCULATED ☐ MEASURED C-43
a. -3 dB
b. -20 dB
c. -60 dB
d. Preselection Type

12. IF FREQUENCY C-43
a. 1st
b. 2nd
c. 3rd

13. MAXIMUM POST DETECTION FREQUENCY C-43

14. MINIMUM POST DETECTION FREQUENCY C-45

15. OSCILLATOR TUNED	1st	2nd	3rd
a. ABOVE TUNED FREQUENCY			C-45
b. BELOW TUNED FREQUENCY			
c. EITHER ABOVE OR BELOW THE FREQUENCY			

16. MAXIMUM BIT RATE C-45

17. SENSITIVITY C-45
a. SENSITIVITY dBm
b. CRITERIA
c. NOISE FIG dB
d. NOISE TEMP Kelvin

18. DE-EMPHASIS (X one)
☐ a. YES ☐ b. NO C-47

19. IMAGE REJECTION C-47

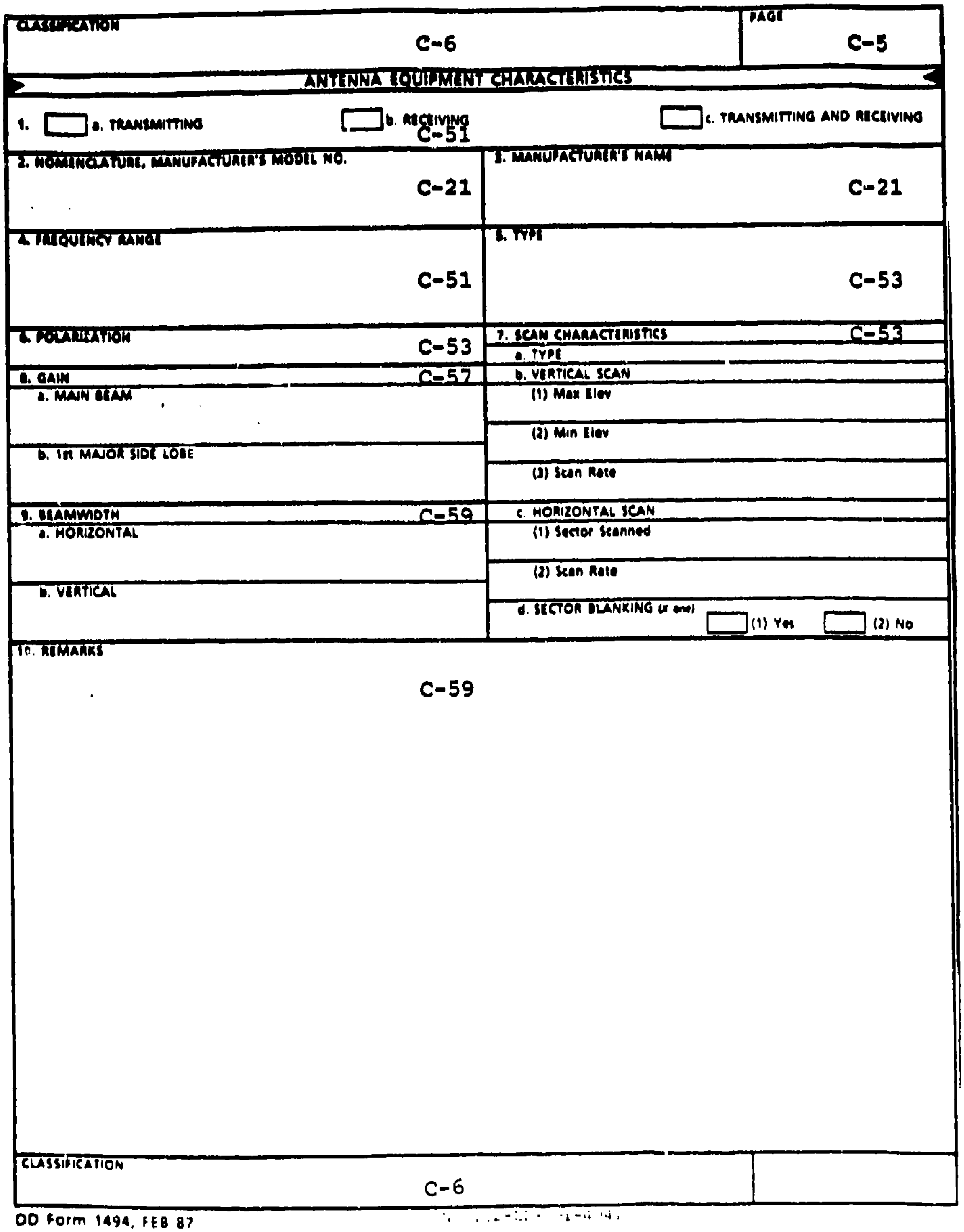
20. SPURIOUS REJECTION C-49

21. REMARKS
C-49

CLASSIFICATION C-6	

DD Form 1494, FEB 87

DD Form 1494 (continued)



CLASSIFICATION C-6	PAGE C-5

ANTENNA EQUIPMENT CHARACTERISTICS

1. ☐ a. TRANSMITTING ☐ b. RECEIVING ☐ c. TRANSMITTING AND RECEIVING
C-51

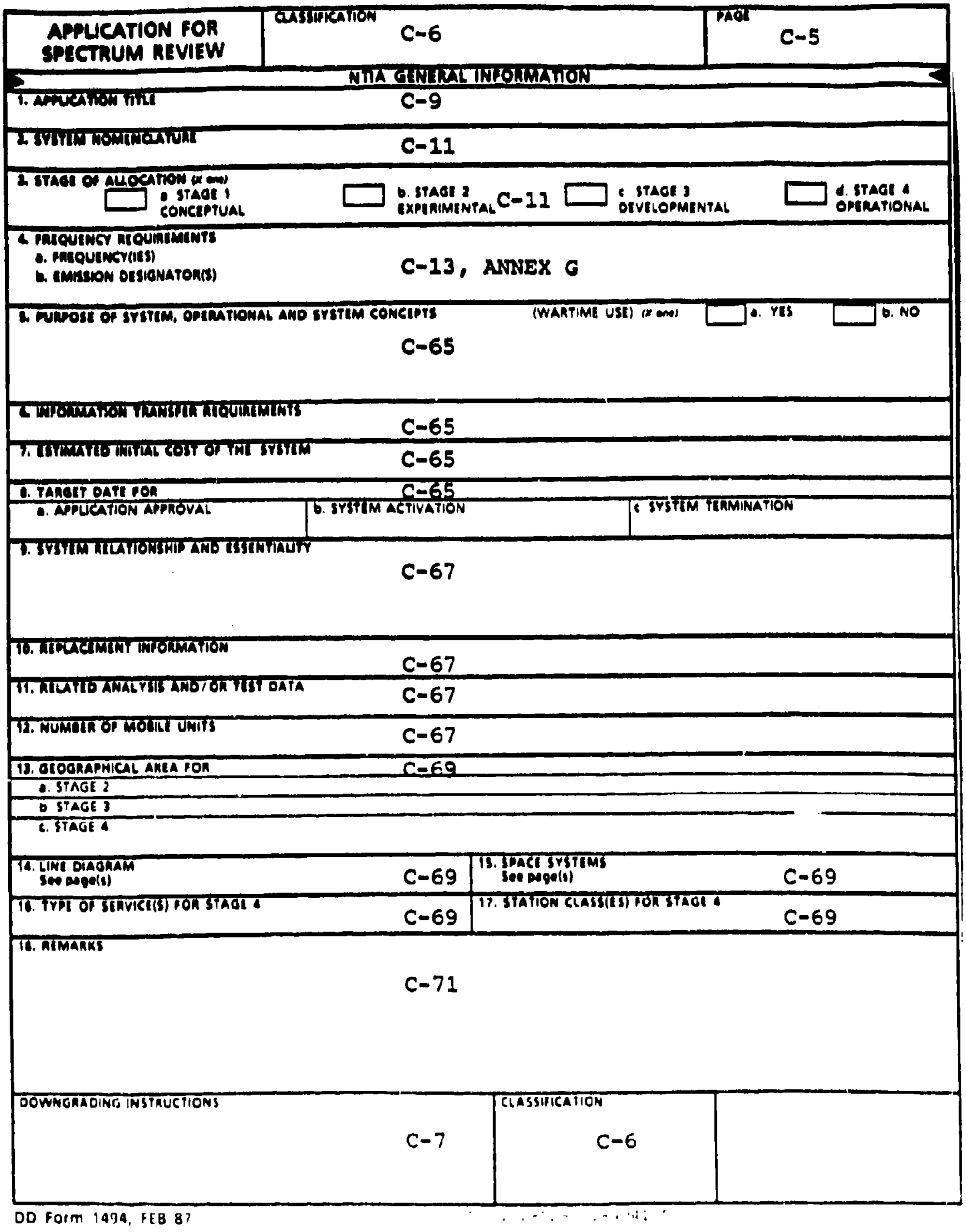
2. NOMENCLATURE, MANUFACTURER'S MODEL NO. C-21	3. MANUFACTURER'S NAME C-21
4. FREQUENCY RANGE C-51	5. TYPE C-53
6. POLARIZATION C-53	7. SCAN CHARACTERISTICS C-53 a. TYPE
8. GAIN C-57	b. VERTICAL SCAN
a. MAIN BEAM	(1) Max Elev
	(2) Min Elev
b. 1st MAJOR SIDE LOBE	(3) Scan Rate
9. BEAMWIDTH C-59	c. HORIZONTAL SCAN
a. HORIZONTAL	(1) Sector Scanned
	(2) Scan Rate
b. VERTICAL	d. SECTOR BLANKING (x one) ☐ (1) Yes ☐ (2) No

10. REMARKS
C-59

CLASSIFICATION C-6	

DD Form 1494, FEB 87

DD Form 1494 (continued)



APPLICATION FOR SPECTRUM REVIEW	CLASSIFICATION C-6	PAGE C-5

NTIA GENERAL INFORMATION

1. APPLICATION TITLE C-9

2. SYSTEM NOMENCLATURE C-11

3. STAGE OF ALLOCATION (X one) ☐ a. STAGE 1 CONCEPTUAL ☐ b. STAGE 2 EXPERIMENTAL C-11 ☐ c. STAGE 3 DEVELOPMENTAL ☐ d. STAGE 4 OPERATIONAL

4. FREQUENCY REQUIREMENTS
a. FREQUENCY(IES)
b. EMISSION DESIGNATOR(S) C-13, ANNEX G

5. PURPOSE OF SYSTEM, OPERATIONAL AND SYSTEM CONCEPTS (WARTIME USE) (X one) ☐ a. YES ☐ b. NO
C-65

6. INFORMATION TRANSFER REQUIREMENTS C-65

7. ESTIMATED INITIAL COST OF THE SYSTEM C-65

8. TARGET DATE FOR C-65
a. APPLICATION APPROVAL b. SYSTEM ACTIVATION c. SYSTEM TERMINATION

9. SYSTEM RELATIONSHIP AND ESSENTIALITY C-67

10. REPLACEMENT INFORMATION C-67

11. RELATED ANALYSIS AND/OR TEST DATA C-67

12. NUMBER OF MOBILE UNITS C-67

13. GEOGRAPHICAL AREA FOR C-69
a. STAGE 2
b. STAGE 3
c. STAGE 4

14. LINE DIAGRAM See page(s) C-69
15. SPACE SYSTEMS See page(s) C-69

16. TYPE OF SERVICE(S) FOR STAGE 4 C-69
17. STATION CLASS(ES) FOR STAGE 4 C-69

18. REMARKS C-71

DOWNGRADING INSTRUCTIONS C-7
CLASSIFICATION C-6

DD Form 1494, FEB 87

DD Form 1494 (continued)

APPLICATION FOR FOREIGN SPECTRUM SUPPORT	CLASSIFICATION C-6	PAGE C-5

FOREIGN COORDINATION GENERAL INFORMATION

1. APPLICATION TITLE
C-9

2. SYSTEM NOMENCLATURE
C-11

3. STAGE OF ALLOCATION (X one)
☐ a. STAGE 1 CONCEPTUAL C-11 ☐ b. STAGE 2 EXPERIMENTAL ☐ c. STAGE 3 DEVELOPMENTAL ☐ d. STAGE 4 OPERATIONAL

4. FREQUENCY REQUIREMENTS
a. FREQUENCY(IES)
b. EMISSION DESIGNATOR(S)
C-13, ANNEX G

5. PROPOSED OPERATING LOCATIONS OUTSIDE US&P
C-73

6. PURPOSE OF SYSTEM, OPERATIONAL AND SYSTEM CONCEPTS
C-65

7. INFORMATION TRANSFER REQUIREMENTS
C-65

8. NUMBER OF UNITS OPERATING SIMULTANEOUSLY IN THE SAME ENVIRONMENT
C-15

9. REPLACEMENT INFORMATION
C-67

10. LINE DIAGRAM See page(s) C-69

11. SPACE SYSTEMS See page(s) C-69

12. PROJECTED OPERATIONAL DEPLOYMENT DATE
C-75

13. REMARKS
C-77

DOWNGRADING INSTRUCTIONS C-7	CLASSIFICATION C-6	

DD Form 1494, FEB 87

APPENDIX H. SFAF MESSAGE FORMAT AND EXAMPLE

A. SFAF MESSAGE FORMAT FOR SPACE SYSTEMS

INFO TYPE	ITEM	DESCRIPTION
Heading	Classification	-
-	Subject	-
-	References	As Required
Administrative Data	005	Security Classification
-	010	Action Type (mod, new, ...)
Emission Characteristics	110	Frequencies
-	113	Station Class
-	114	Emission Designator
-	115	Transmitter Power
Date-Time Information	130	Time
-	140	Required Date
-	141	Expiration Date
-	144	IRAC Record Indicator
Organizational Information	200	Agency
-	203	Area FMO Bureau
-	207	Operating Unit
-	208	User Net Code
Transmitter Location Data	300	State Country
-	301	Antenna Location
-	303	Antenna Coordinates
-	306 (1)(4)	Auth. Mileage Radius
Transmitter on Space Stations	314	Space Defense Center Object Number
-	315	Inclination (°)
-	316	Apogee (statute miles)
-	317	Perigee (statute miles)
-	318	Orbital Period
-	319	Number of Satellites
-	321	Power Density (dbW)

Transmitter Equipment	340	Equipment Nomenclature
•	343	Equip Allocation Status
Transmitter Antenna Data	354 (4)	Antenna Name
•	357	Antenna Gain
•	358 (4)	Ant Elevation (ft MSL)
•	359 (4)	Antenna Feed Point Height (ft from ground)
•	360	Beamwidth (°)
•	362	Orientation
•	363	Polarization
Receiver Location Data	400	State/Country
•	401	Antenna Location
•	403	Antenna Coordinates
•	406 (5)	Auth Mileage Radius (for mobile equipment)
Receivers on Space Stations	414 (2)(4)	Space Defense Center Object Number
•	415 (2)(4)	Inclination (°)
•	416 (2)(4)	Apogee (statute miles)
•	417 (2)(4)	Perigee (statute miles)
•	418 (2)(4)	Orbital Period (hours)
•	419 (2)(4)	Number of Satellites
Receiver Equipment	440	Equipment Nomenclature
Receiver Antenna Data	443	Equip Allocation Status
•	454 (5)	Antenna Name
•	455 (5)	Antenna Nomenclature
•	457	Gain (dB)
•	458 (5)	Ant Elevation (ft MSL)
•	459 (5)	Antenna Feed Point Height (ft from ground)
•	460	Beamwidth (°)
•	462	Orientation
•	463	Polarization
Space Systems	470 (4)	Space Station Receiving Noise Temp. (°K)
•	471 (5)	Earth Station Receiving Noise Temp. (°K)
•	472	Equiv Satellite Link Noise Temp. (°K)

Supplementary Details	502	Description of Requirement
Add. Assignment Identifiers	711 (3)	Aeronautical Service Range and Height
Additional Information	801	Coordination Data, Remarks
	803	Requestor Data

Notes:

(1) For mobile earth station only
(2) For non-geostationary satellites
(3) Denote ##K altitude for airborne stations
(4) Earth-to-space only
(5) Space-to-earth only

B. SAMPLE SFAF FOR AN EARTH-TO-SPACE SYSTEM

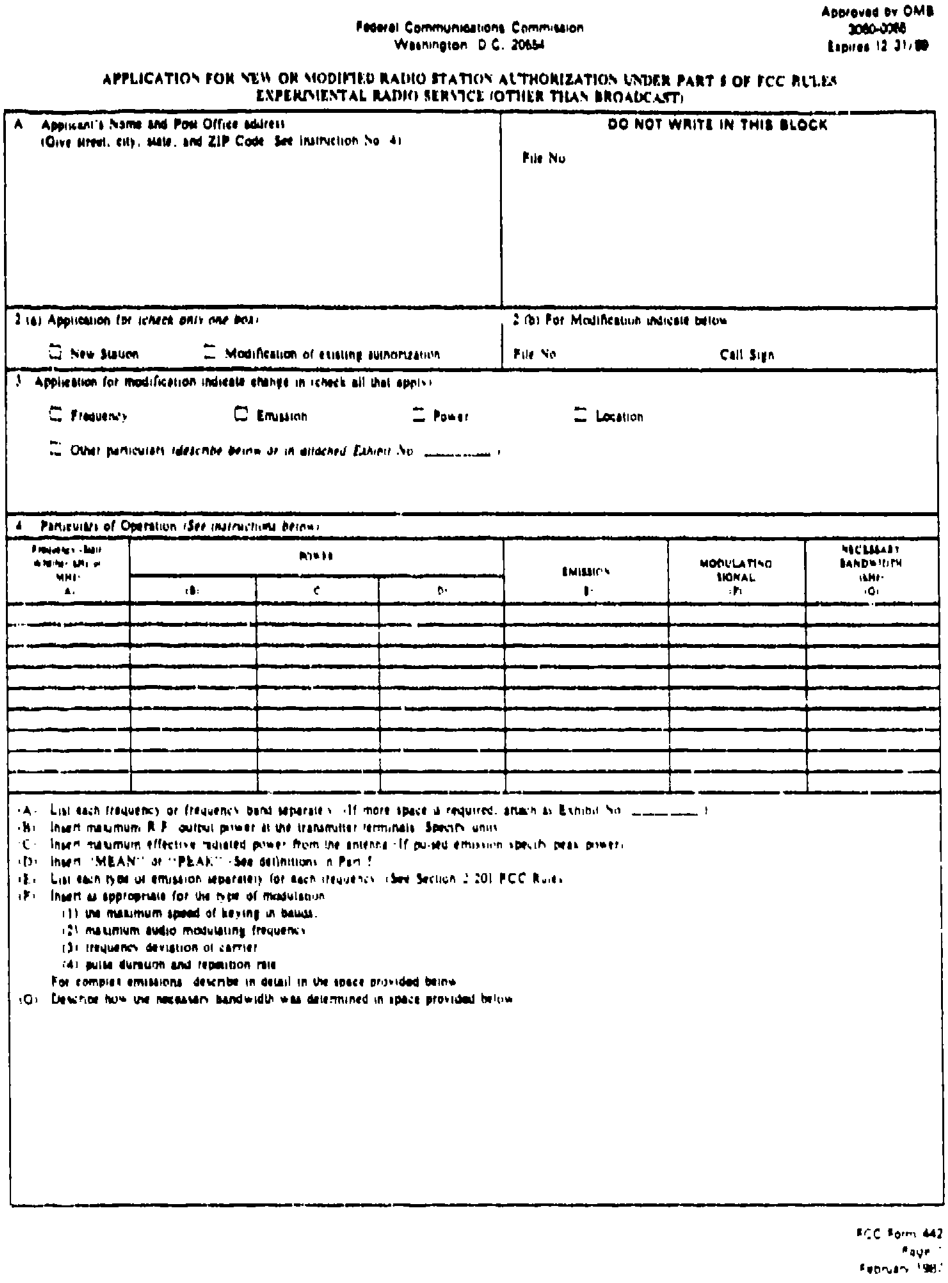
UNCLAS

SUBJ: FREQUENCY ASSIGNMENT/NPS PANSAT

005. U
010. N
110. M436-438
113. TT
114. 1M00G1D
115. W100
130. 1H24
140. 910730
141. 940730
144. Y
200. USN
203. WS
207. NPS
208. 31405
300. CAL
301. MONTEREY
303. 370821N1321039W
306. N/A
314. NONE
315. 28.4
316. 480
317. 480
318. 1.52H
319. I
321. -53
340. XXXXXXXXXX (Need nomenclature for type of radio)
343. J1269
354. LINEAR
357. 0
358. 120
359. 60
360. 360

362. ND
363. L/R
400. N/A
401. NONGEOS
403. N/A
406. N/A
414. NONE
415. 28.7
416. 304
417. 304
418. 1.52H
419. 1
440. XXXXXXXXXXX (need radio nomenclature)
443. J1269
454. N/A
455. N/A
457. 0
458. N/A
459. N/A
460. 360
462. ND
463. L/R
470. 1000
471. N/A
472. 96
502. EXPERIMENTATION AS AN ON-ORBIT LABORATORY FOR SPACE SYSTEMS CURRICULA AT NPS
711. N/A
801. NAFC/NAFC MSG 021200Z FEB 90
803. JOE GISH, AV 555-5551

APPENDIX I. SAMPLE FCC FORM 442



Federal Communications Commission
Washington D.C. 20554

Approved by OMB
3060-0058
Expires 12/31/89

APPLICATION FOR NEW OR MODIFIED RADIO STATION AUTHORIZATION UNDER PART 5 OF FCC RULES EXPERIMENTAL RADIO SERVICE (OTHER THAN BROADCAST)

A Applicant's Name and Post Office address
(Give street, city, state, and ZIP Code. See Instruction No. 4)

DO NOT WRITE IN THIS BLOCK

File No

2 (a) Application for *(check only one box)*

☐ New Station ☐ Modification of existing authorization

2 (b) For Modification indicate below

File No Call Sign

3 Application for modification indicate change in *(check all that apply)*

☐ Frequency ☐ Emission ☐ Power ☐ Location

☐ Other particulars *(describe below or in attached Exhibit No ________)*

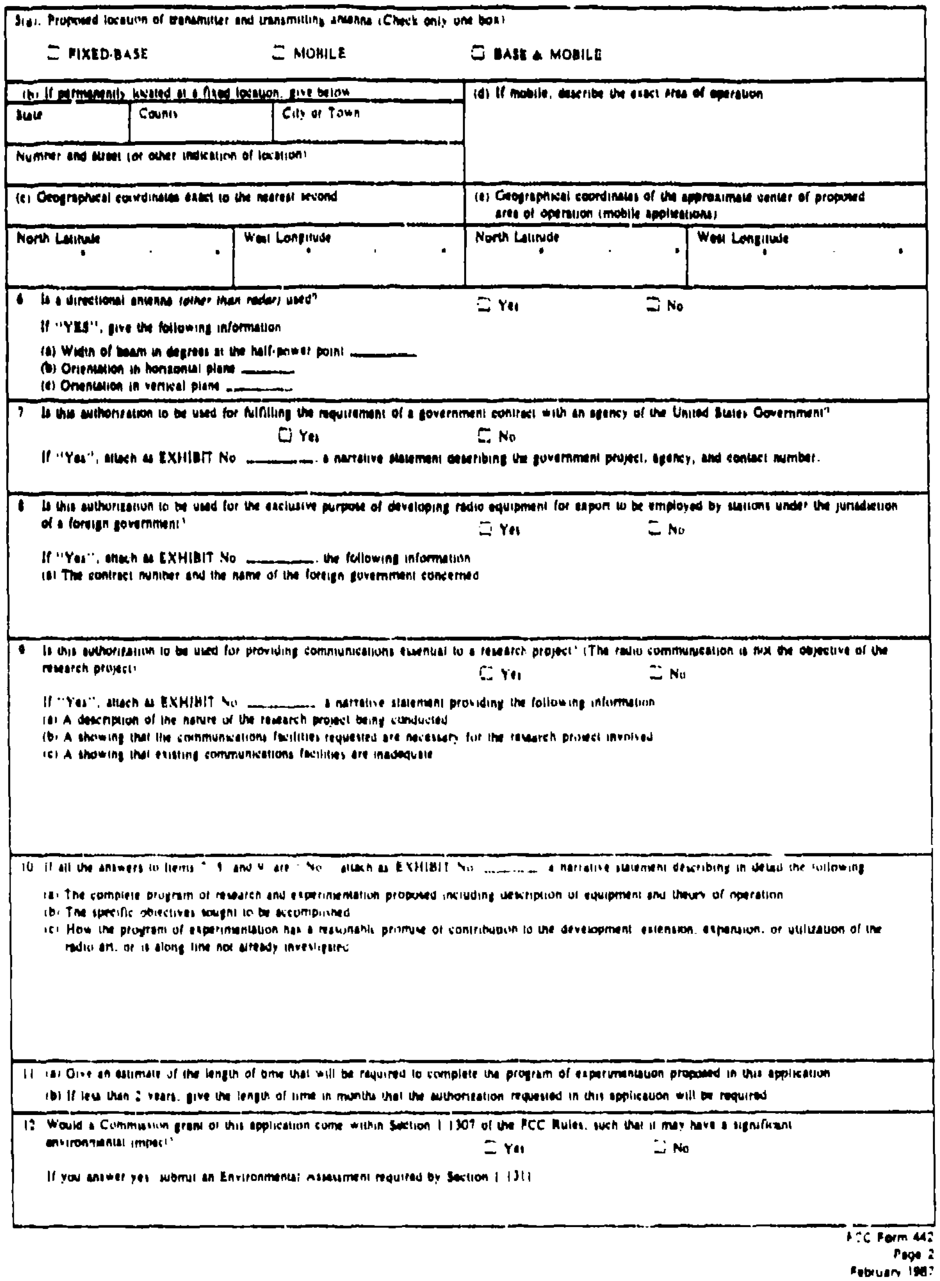
4 Particulars of Operation *(See instructions below)*

FREQUENCY (kHz or MHz) (A)	POWER			EMISSION (E)	MODULATING SIGNAL (F)	NECESSARY BANDWIDTH (kHz) (G)
	(B)	(C)	(D)			

(A) List each frequency or frequency band separately. (If more space is required, attach as Exhibit No ________)
(B) Insert maximum R.F. output power at the transmitter terminals. Specify units.
(C) Insert maximum effective radiated power from the antenna. (If pulsed emission specify peak power)
(D) Insert "MEAN" or "PEAK" (See definitions in Part 5)
(E) List each type of emission separately for each frequency. (See Section 2.201 FCC Rules)
(F) Insert as appropriate for the type of modulation
  (1) the maximum speed of keying in bauds.
  (2) maximum audio modulating frequency
  (3) frequency deviation of carrier
  (4) pulse duration and repetition rate
  For complex emissions, describe in detail in the space provided below.
(G) Describe how the necessary bandwidth was determined in space provided below

FCC Form 442
Page 1
February 1987

FCC Form 442 (continued)



5(a). Proposed location of transmitter and transmitting antenna (Check only one box)

☐ FIXED-BASE ☐ MOBILE ☐ BASE & MOBILE

(b) If permanently located at a fixed location, give below

State	County	City or Town
Number and street (or other indication of location)		

(d) If mobile, describe the exact area of operation

(c) Geographical coordinates exact to the nearest second

(e) Geographical coordinates of the approximate center of proposed area of operation (mobile applications)

North Latitude ° ' "	West Longitude ° ' "	North Latitude ° ' "	West Longitude ° ' "

6 Is a directional antenna *(other than radar)* used? ☐ Yes ☐ No

If "YES", give the following information

(a) Width of beam in degrees at the half-power point ______

(b) Orientation in horizontal plane ______

(c) Orientation in vertical plane ______

7 Is this authorization to be used for fulfilling the requirement of a government contract with an agency of the United States Government?

☐ Yes ☐ No

If "Yes", attach as EXHIBIT No ______ a narrative statement describing the government project, agency, and contact number.

8 Is this authorization to be used for the exclusive purpose of developing radio equipment for export to be employed by stations under the jurisdiction of a foreign government? ☐ Yes ☐ No

If "Yes", attach as EXHIBIT No ______ the following information

(a) The contract number and the name of the foreign government concerned

9 Is this authorization to be used for providing communications essential to a research project? (The radio communication is not the objective of the research project) ☐ Yes ☐ No

If "Yes", attach as EXHIBIT No ______ a narrative statement providing the following information

(a) A description of the nature of the research project being conducted

(b) A showing that the communications facilities requested are necessary for the research project involved

(c) A showing that existing communications facilities are inadequate

10 If all the answers to items 7, 8 and 9 are "No", attach as EXHIBIT No ______ a narrative statement describing in detail the following

(a) The complete program of research and experimentation proposed including description of equipment and theory of operation

(b) The specific objectives sought to be accomplished

(c) How the program of experimentation has a reasonable promise of contribution to the development, extension, expansion, or utilization of the radio art, or is along line not already investigated

11 (a) Give an estimate of the length of time that will be required to complete the program of experimentation proposed in this application

(b) If less than 2 years, give the length of time in months that the authorization requested in this application will be required

12 Would a Commission grant of this application come within Section 1.1307 of the FCC Rules, such that it may have a significant environmental impact? ☐ Yes ☐ No

If you answer yes, submit an Environmental Assessment required by Section 1.1311

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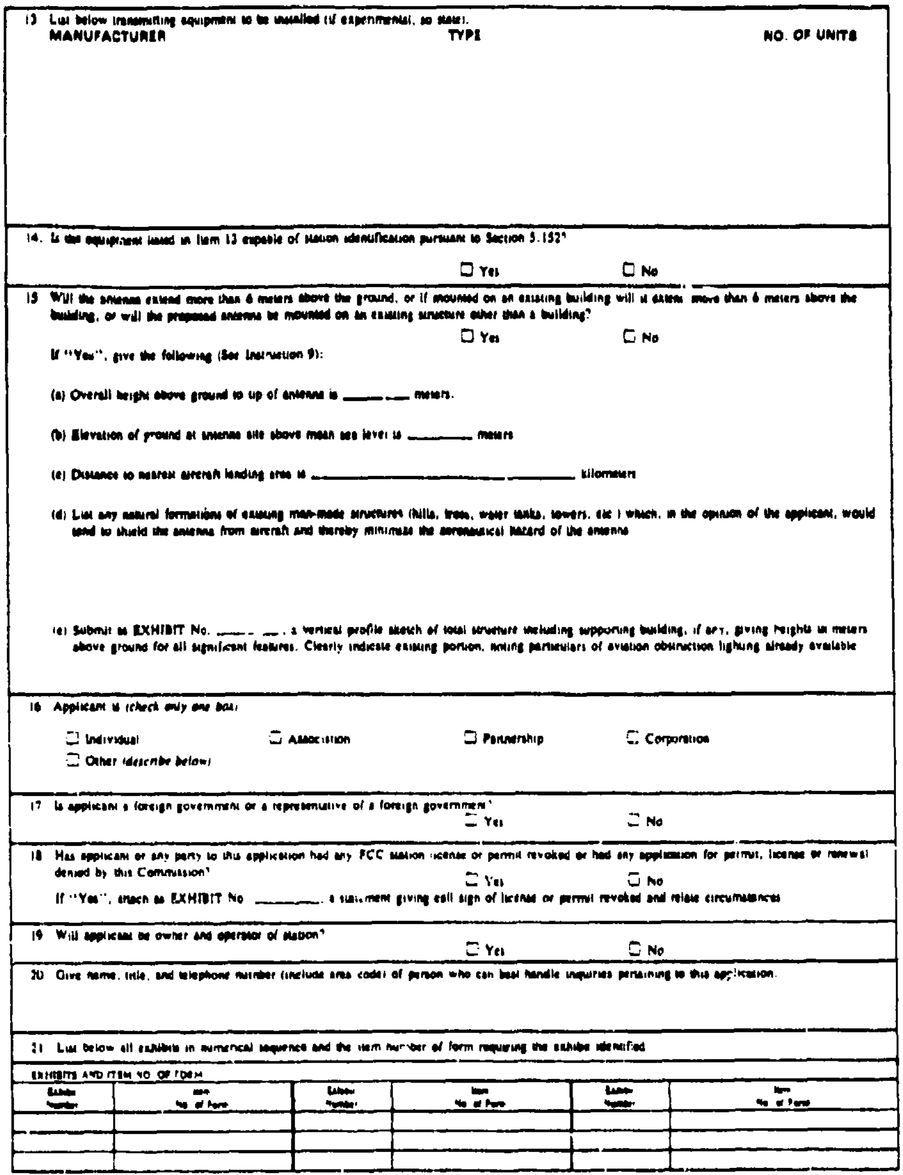
FCC Form 442 (continued)



13 List below transmitting equipment to be installed (if experimental, so state).

MANUFACTURER	TYPE	NO. OF UNITS

14. Is the equipment listed in Item 13 capable of station identification pursuant to Section 5.152?

☐ Yes ☐ No

15 Will the antenna extend more than 6 meters above the ground, or if mounted on an existing building will it extend more than 6 meters above the building, or will the proposed antenna be mounted on an existing structure other than a building?

☐ Yes ☐ No

If "Yes", give the following (See Instruction 9):

(a) Overall height above ground to tip of antenna is ________ meters.

(b) Elevation of ground at antenna site above mean sea level is ________ meters

(c) Distance to nearest aircraft landing area is ________________ kilometers

(d) List any natural formations or existing man-made structures (hills, trees, water tanks, towers, etc.) which, in the opinion of the applicant, would tend to shield the antenna from aircraft and thereby minimize the aeronautical hazard of the antenna

(e) Submit as EXHIBIT No. ________, a vertical profile sketch of total structure including supporting building, if any, giving heights in meters above ground for all significant features. Clearly indicate existing portion, noting particulars of aviation obstruction lighting already available

16 Applicant is *(check only one box)*

☐ Individual ☐ Association ☐ Partnership ☐ Corporation
☐ Other *(describe below)*

17 Is applicant a foreign government or a representative of a foreign government?

☐ Yes ☐ No

18 Has applicant or any party to this application had any FCC station license or permit revoked or had any application for permit, license or renewal denied by this Commission?

☐ Yes ☐ No

If "Yes", attach as EXHIBIT No ________, a statement giving call sign of license or permit revoked and relate circumstances

19 Will applicant be owner and operator of station?

☐ Yes ☐ No

20 Give name, title, and telephone number (include area code) of person who can best handle inquiries pertaining to this application.

21 List below all exhibits in numerical sequence and the item number of form requiring the exhibit identified

EXHIBITS AND ITEM NO. OF FORM

Exhibit Number	Item No. of Form	Exhibit Number	Item No. of Form	Exhibit Number	Item No. of Form

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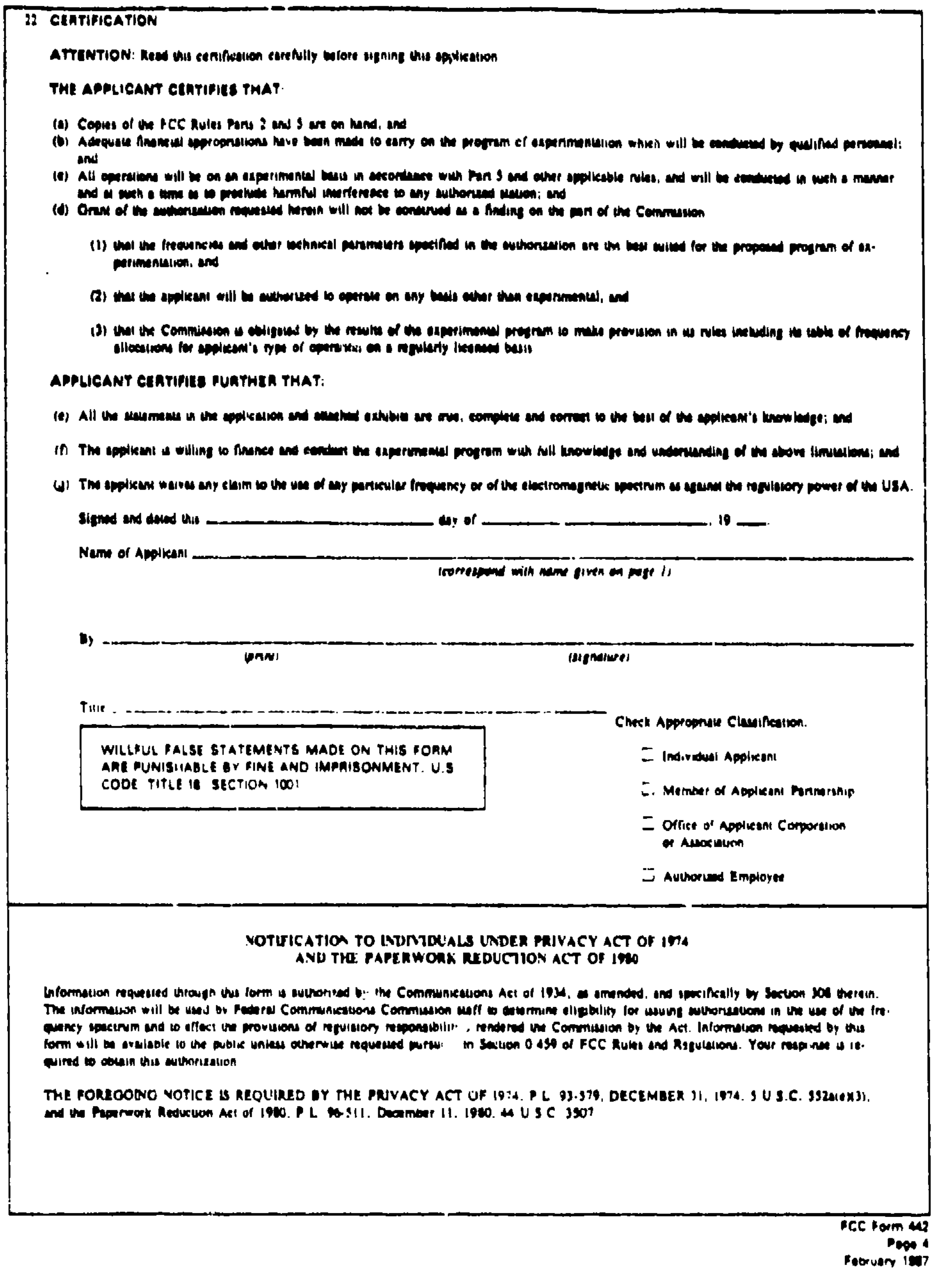
FCC Form 442 (continued)



22 **CERTIFICATION**

ATTENTION: Read this certification carefully before signing this application

THE APPLICANT CERTIFIES THAT:

(a) Copies of the FCC Rules Parts 2 and 5 are on hand, and
(b) Adequate financial appropriations have been made to carry on the program of experimentation which will be conducted by qualified personnel; and
(c) All operations will be on an experimental basis in accordance with Part 5 and other applicable rules, and will be conducted in such a manner and at such a time as to preclude harmful interference to any authorized station; and
(d) Grant of the authorization requested herein will not be construed as a finding on the part of the Commission

(1) that the frequencies and other technical parameters specified in the authorization are the best suited for the proposed program of experimentation, and

(2) that the applicant will be authorized to operate on any basis other than experimental, and

(3) that the Commission is obligated by the results of the experimental program to make provision in its rules including its table of frequency allocations for applicant's type of operation on a regularly licensed basis

APPLICANT CERTIFIES FURTHER THAT:

(e) All the statements in the application and attached exhibits are true, complete and correct to the best of the applicant's knowledge; and

(f) The applicant is willing to finance and conduct the experimental program with full knowledge and understanding of the above limitations; and

(g) The applicant waives any claim to the use of any particular frequency or of the electromagnetic spectrum as against the regulatory power of the USA.

Signed and dated this ______________ day of ______________, 19 ____.

Name of Applicant ______________________________
(correspond with name given on page 1)

By ______________________________ ______________________________
(print) *(signature)*

Title ______________________________

WILLFUL FALSE STATEMENTS MADE ON THIS FORM ARE PUNISHABLE BY FINE AND IMPRISONMENT. U.S CODE TITLE 18 SECTION 1001

Check Appropriate Classification.

☐ Individual Applicant

☐ Member of Applicant Partnership

☐ Office of Applicant Corporation or Association

☐ Authorized Employee

NOTIFICATION TO INDIVIDUALS UNDER PRIVACY ACT OF 1974 AND THE PAPERWORK REDUCTION ACT OF 1980

Information requested through this form is authorized by the Communications Act of 1934, as amended, and specifically by Section 308 therein. The information will be used by Federal Communications Commission staff to determine eligibility for issuing authorizations in the use of the frequency spectrum and to effect the provisions of regulatory responsibility rendered the Commission by the Act. Information requested by this form will be available to the public unless otherwise requested pursuant to Section 0.459 of FCC Rules and Regulations. Your response is required to obtain this authorization

THE FOREGOING NOTICE IS REQUIRED BY THE PRIVACY ACT OF 1974, P.L. 93-579, DECEMBER 31, 1974, 5 U.S.C. 552a(e)(3), and the Paperwork Reduction Act of 1980, P.L. 96-511, December 11, 1980, 44 U.S.C. 3507

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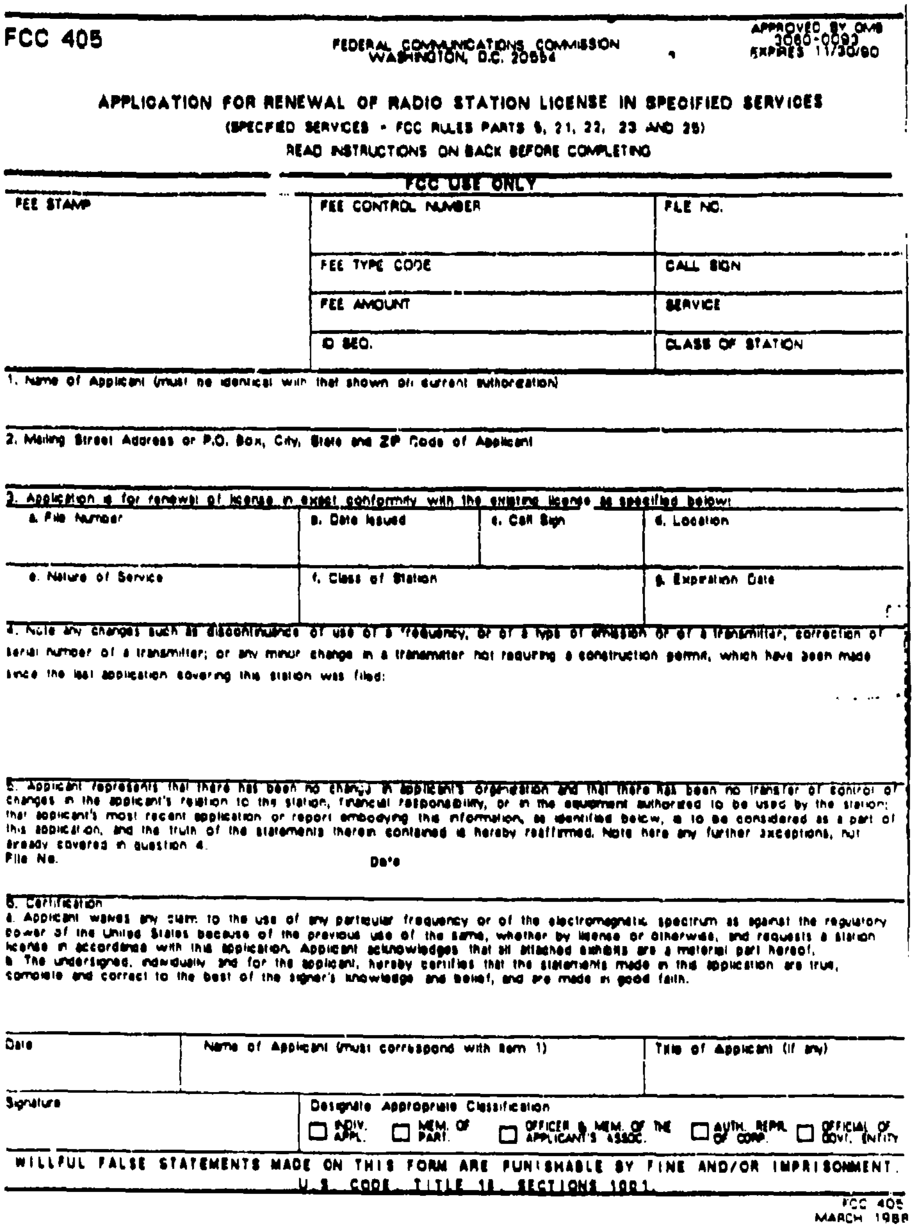
APPENDIX J. SAMPLE FCC FORM 405



FCC 405

FEDERAL COMMUNICATIONS COMMISSION
WASHINGTON, D.C. 20554

APPROVED BY OMB
3060-0093
EXPIRES 11/30/90

APPLICATION FOR RENEWAL OF RADIO STATION LICENSE IN SPECIFIED SERVICES
(SPECIFIED SERVICES - FCC RULES PARTS 5, 21, 22, 23 AND 25)
READ INSTRUCTIONS ON BACK BEFORE COMPLETING

	FCC USE ONLY	
FEE STAMP	FEE CONTROL NUMBER	FILE NO.
	FEE TYPE CODE	CALL SIGN
	FEE AMOUNT	SERVICE
	ID SEQ.	CLASS OF STATION

1. Name of Applicant (must be identical with that shown on current authorization)

2. Mailing Street Address or P.O. Box, City, State and ZIP Code of Applicant

3. Application is for renewal of license in exact conformity with the existing license as specified below:

a. File Number	b. Date Issued	c. Call Sign	d. Location
e. Nature of Service	f. Class of Station		g. Expiration Date

4. Note any changes such as discontinuance of use of a frequency, or of a type of emission or of a transmitter, correction of serial number of a transmitter; or any minor change in a transmitter not requiring a construction permit, which have been made since the last application covering this station was filed:

5. Applicant represents that there has been no change in applicant's organization and that there has been no transfer of control or changes in the applicant's relation to the station, financial responsibility, or in the equipment authorized to be used by the station; that applicant's most recent application or report embodying this information, as identified below, is to be considered as a part of this application, and the truth of the statements therein contained is hereby reaffirmed. Note here any further exceptions, not already covered in question 4.

File No. Date

6. Certification

a. Applicant waives any claim to the use of any particular frequency or of the electromagnetic spectrum as against the regulatory power of the United States because of the previous use of the same, whether by license or otherwise, and requests a station license in accordance with this application. Applicant acknowledges that all attached exhibits are a material part hereof.

b. The undersigned, individually and for the applicant, hereby certifies that the statements made in this application are true, complete and correct to the best of the signer's knowledge and belief, and are made in good faith.

Date	Name of Applicant (must correspond with item 1)	Title of Applicant (if any)
Signature	Designate Appropriate Classification ☐ INDIV. APPL. ☐ MEM. OF PART. ☐ OFFICER & MEM. OF THE APPLICANT'S ASSOC. ☐ AUTH. REPR. OF CORP. ☐ OFFICIAL OF GOVT. ENTITY	

WILLFUL FALSE STATEMENTS MADE ON THIS FORM ARE PUNISHABLE BY FINE AND/OR IMPRISONMENT.
U.S. CODE, TITLE 18, SECTIONS 1001.

FCC 405
MARCH 1988

LIST OF REFERENCES

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